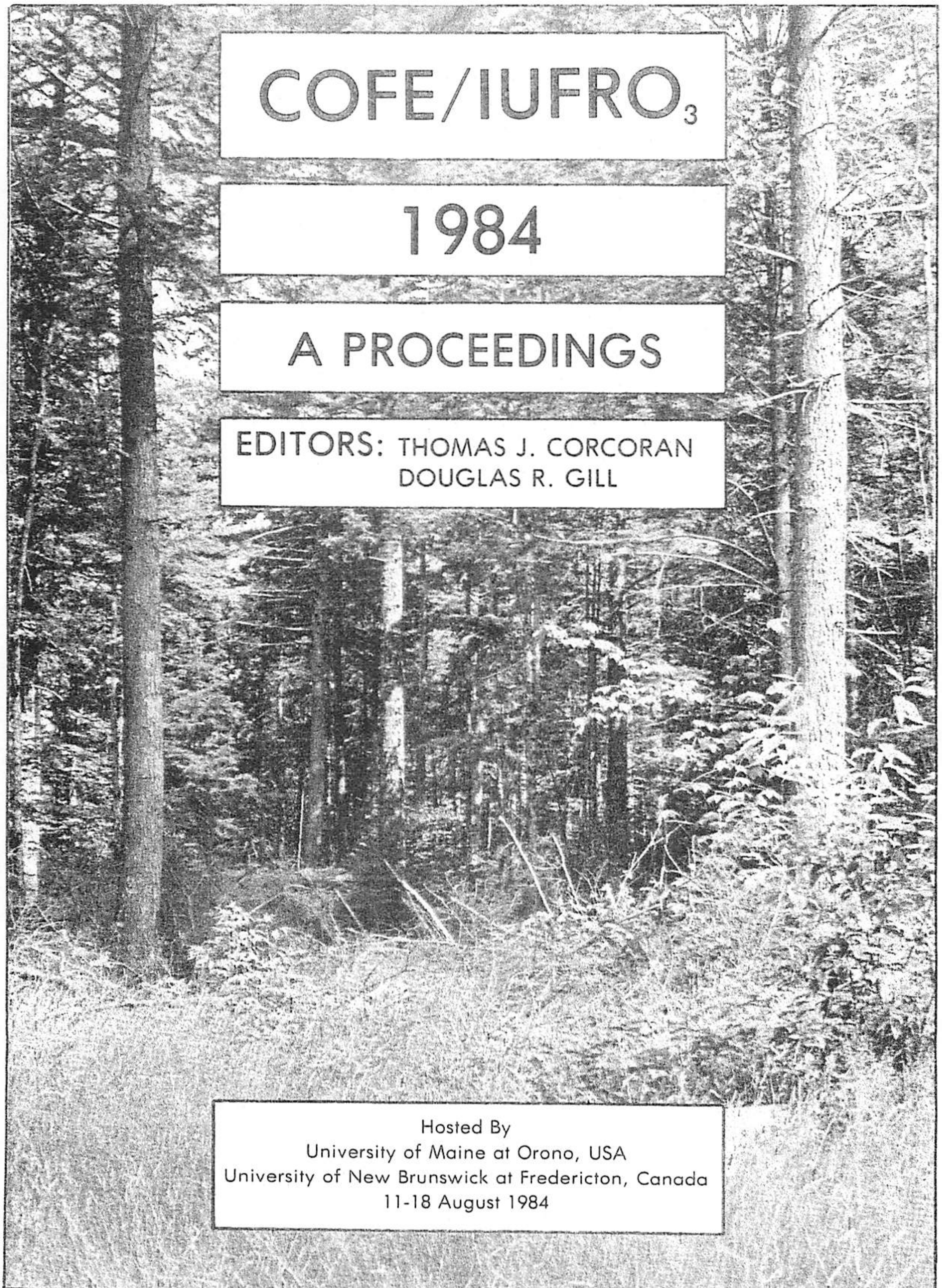
INTERNATIONAL UNION OF FOREST RESEARCH ORGANIZATIONS

COUNCIL ON FOREST ENGINEERING



COFE/IUFRO[3]

1984

A PROCEEDINGS

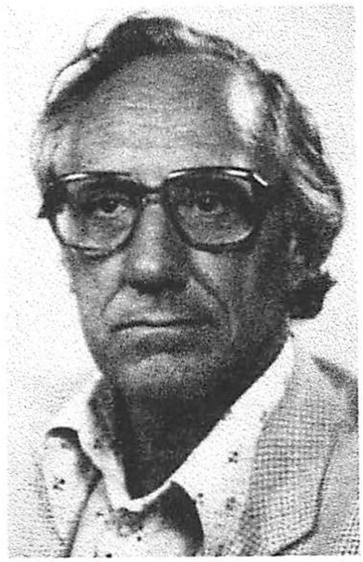
EDITORS: THOMAS J. CORCORAN
DOUGLAS R. GILL

Hosted By
University of Maine at Orono, USA
University of New Brunswick at Fredericton, Canada
11-18 August 1984

CONFERENCE ORGANIZING COMMITTEE

THOMAS C. BJERKELUND

Thomas C. Bjerkelund is Professor of Forest Engineering and Chairman of the Department at the University of New Brunswick. Since joining UNB in 1970, Tom has taught courses in tree harvesting concepts, forest operations, and system analysis and planning. Prior to teaching, he was employed for twenty-one years with the woodlands divisions of several Canadian pulp and paper companies. His industrial responsibilities pertained to forest operations and included technology and management as well as research and development. He is a past Chairman of COFE and is currently a Deputy Coordinator for Division 3, IUFRO.



MARTEN BOL

Marten Bol is currently Coordinator for Division 3, IUFRO, and as such he is a member of the Executive Board for IUFRO. He is a Professor and department head for the Department of Forest Technique and Forest Products, Agricultural University of Wageningen, the Netherlands. Marten has held numerous international offices over the past years and also is President of the Royal Dutch Forestry Society.

THOMAS J. CORCORAN

Thomas J. Corcoran, Professor of Forest Economics and of Forest Engineering, has teaching, research, and administrative responsibilities in forest engineering and the FORMULA group of the College of Forest Resources, University of Maine at Orono. He is Technical Coordinator of the Society of the American Foresters for New England and Chairman of the Society's Region VI (New England and New York) Technical Committee. He is also Chairman of COFE and Chairman of IUFRO subject area 3.04. Tom has held numerous international fellowships, including the Senior Fulbright Research Scholar (Finland), NATO Senior Fellow (Norway), and NATO Senior Scientist (Netherlands). He holds a B.S. (1955) from Michigan Technological University, and a M.S. (1960) and Ph.D. (1962) from Purdue University in Indiana.

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ABSTRACTS OF POSTERS PRESENTED

INTERNATIONAL UNION OF FORESTRY RESEARCH ORGANIZATIONS (Division 3)

COUNCIL ON FOREST ENGINEERING

AGENDA

COFE/IUFRO, 1984
U.S.A. PROGRAM

Friday, August 10 - Maine, USA

(Afternoon) Arrival in Orono/Bangor, Maine - UMO
Dormitory Check-in - Kennebec Hall

(Evening) Dinner at York Commons (1730-1830)

Saturday, August 11 - Maine, USA

(Morning) Breakfast at York Commons (0700-0800)
Tours (0900-1130)

a) University Forest (0900-1030)
b) Nutting Hall (0900-1130)
c) UMO Campus (0900-1130)

(Afternoon) Lunch at York Commons (1130-1230)
Tours (1245-1715)

a) Bangor shopping (1245-1715)
b) Acadia National Park (1215-2030)

(Evening) Dinner at York Commons (1730-1830)

a) Optional Subject/Working Group IUFRO meeting (1930-2130)
b) TV movies (1930-2200)

Sunday, August 12 - Maine, USA

(Morning) Breakfast at York Commons (0700-0800)

(Afternoon) Lunch at York Commons (1130-1230)
Registration (1000-1400)
*IUFRO Division 3 Business (1315-1415)
Marten Bol, Presiding (100 Nutting)
Coordinator, IUFRO Division 3
Agricultural University of The Netherlands
*Refreshments available (1400-1600)
*COFE Business (1415-1530)
Thomas Corcoran, Presiding (100 Nutting)
Chairman, COFE
University of Maine at Orono, USA

*Optional Fort Knox tour for spouses (1215-1730).

Session A - Benjamin Hoffman, Presiding (100 Nutting)
Associate Professor
University of Maine at Orono, USA

1530-1545 Welcoming Remarks - Gregory Brown, Dean
College of Forest Resources
University of Maine at Orono, USA

1545-1615 "PAPER, FIBER AND WOOD PRODUCTS - AN ECONOMIC PROSPECTUS"
Ben Slatin
American Paper Institute
New York, New York USA

1615-1635 "A SUMMARY OF CURRENT FOREST ENGINEERING RESEARCH AND DEVELOPMENT IN THE UNITED STATES AND CANADA"
John W. Mann
Oregon State University
Corvallis, Oregon USA

1635-1655 "RESEARCH ON LOGGING SYSTEMS"
John A. Miles
University of California at Davis
Davis, California USA

1655-1705 Discussion

1705-1715 Field Excursions and other procedural details

(Evening) Ice Breaker for all participants at
Kennebec Hall Lounge (1800-1900)
Dinner at York Commons (1900-2000)
Subject/Working Group IUFRO Meetings (2000-2100)

Monday, August 13 - Maine, USA

(Morning) Breakfast at York Commons (0700-0745)

Session B - Willem Heij, Presiding (100 Nutting)
Ingenieur
Agricultural University of The Netherlands
Wageningen, The Netherlands

0800-0820 "POLAR CO-ORDINATES CHARTS IN OPERATIONAL DECISIONS"
Adolf Schlaghamersky
Technical College Hildesheim
Gottingen, West Germany

0820-0840 "PREDICTING PRODUCTIVITY USING INTERACTIVE SKIDDING MODELS"
Eldon D. Olsen
Oregon State University
Corvallis, Oregon USA

0840-0850 Discussion

Session B continued

0850-0910 "ANALYZING AND SIMULATING TIMBERYARDS"
Helmut Lohmann (with Hubertus Lehnhausen)
University of Gottingen
Gottingen, West Germany

0910-0930 "GUIDELINES FOR THE DEVELOPMENT AND USE OF SIMULATION MODELS"
Dennis B. Webster
Auburn University
Auburn, Alabama USA

0930-0940 Discussion

0940-0950 Intermission

Session C - Thomas Bjerkelund, Presiding (100 Nutting)
Professor
University of New Brunswick
Fredericton, New Brunswick, Canada

0950-1010 "RECENT RESEARCH AND DEVELOPMENT OF ANCHORING SYSTEMS FOR CABLE LOGGING OPERATIONS"
Ronald L. Copstead
Pacific Northwest Forest & Range Experiment Station
U.S. Forest Service
Seattle, Washington USA

1010-1030 "NON-SHEAR FELLING MACHINERY IN BRITISH COLUMBIA"
Bruce A. McMorland
Forest Engineering Research Institute of Canada
Vancouver, British Columbia, Canada

1030-1040 Discussion

1040-1100 "PRODUCTIVITY OF THE VALMET 940 GP GRAPPLE PROCESSOR IN SOUTHERN PINE PLANTATION THINNING"
W. Dale Greene (with B. L. Lanford)
Auburn University
Auburn, Alabama USA

1100-1120 "SKIDDERS USING HIGH FLOATATION TIRES"
Brent J. Sauder
MacMillan Bloedel Limited
Vancouver, British Columbia, Canada

1120-1140 "FORCES AND OBSTACLES IN THE MECHANIZATION OF FOREST OPERATIONS IN SWEDEN"
Stig Andersson
Skogsarbeten
Spanga, Sweden

1140-1150 Discussion

Lunch at York Commons (1150-1300)

Poster sessions will be concurrent with some presentations of papers in Sessions C and D. A listing of poster presentations and authors is provided below. Posters will be manned from 0930-0950, 1220-1350, and 1430-1450 in Rooms 102, 106 and hallway off Room 257 in Nutting Hall.

"ROLL SPLITTER USE ON SOUTHERN HARDWOODS"
Dennis T. Curtin
Tennessee Valley Authority
Norris, Tennessee USA

"SPRUCE BUDWORM IN MAINE"
David E. Fosbroke (with D. Gill and T. Corcoran)
University of Maine at Orono
Orono, Maine USA

"MECHANIZED SHORTWOOD THINNING SYSTEM"
Bobby L. Lanford (with B. Stokes)
Auburn University
Auburn, Alabama USA

"ROAD AND BRIDGE CONSTRUCTION"
A. Allen Murphy
Seven Islands Company
Bangor, Maine USA

"A MAP-BASED INFORMATION SYSTEM FOR LOGGING ROAD MANAGEMENT"
Maarten A. Nieuwenhuis (with T. Corcoran)
University of Maine of Orono
Orono, Maine USA

"PENDULUM SWING BALLOON LOGGING"
Eldon D. Olsen
Oregon State University
Corvallis, Oregon USA

"MICROCOMPUTER-BASED FOREST OPERATIONAL PLANNING DECISION SUPPORT SYSTEMS"
E. W. Robak
University of New Brunswick
Fredericton, New Brunswick, Canada

"THE EFFECT OF HEAT STRESS ON FOREST HARVESTING PRODUCTIVITY"
Leo A. Smith (with M. Seay and D. Sirois)
Auburn University
Auburn, Alabama USA

"RESIDUAL HARVESTING SYSTEMS FOR THE SOUTH"
Bryce J. Stokes (with D. Sirois)
Southern Forest Experiment Station
U.S. Forest Service
Auburn, Alabama USA

(Afternoon)

Session D - Pentti Hakkila, Presiding (100 Nutting)
Professor
Finnish Forest Research Institute
Helsinki, Finland

1300-1320 "FUELWOOD PROCUREMENT FOR AN INDUSTRIAL POWER PLANT: CASE STUDY OF DOW CORNING'S POWER"
Charles T. Bond (with P. Sworden and G. Folger)
Dow Corning Corporation
Midland, Michigan USA

1320-1340 "HEATING SYSTEMS IN SWEDEN WITH ENERGY FROM FOREST BIOMASS"
Bo Hakansson
Swedish University of Agricultural Sciences
Garpenberg, Sweden

1340-1350 Discussion

1350-1410 "FOREST ROAD BALLAST AND SURFACE ROCK"
William A. Johnson
Department of Natural Resources
State of Washington
Lacey, Washington USA

1410-1430 "CONSTRUCTION OF ENVIRONMENTALLY SOUND FOREST ROADS IN THE PACIFIC NORTHWEST"
Sandor Nagygyor
Bureau of Land Management
U.S. Department of the Interior
Eugene, Oregon USA

1430-1440 Discussion

1440-1450 Intermission

Session E - James E. Shottafer, Presiding (100 Nutting)
Professor
University of Maine at Orono
Orono, Maine USA

1450-1510 "QUALITY IMPROVEMENTS IN WORK STUDY USING THE HANDHELD CALCULATOR/COMPUTER"
Jan T. Clausen
Skovteknisk Institute
Copenhagen, Denmark

1510-1530 "PRODUCTION TIME-STUDY TECHNIQUES - A REVIEW OF APPLICATIONS"
Benjamin F. Hoffman (with M. Cameron)
University of Maine at Orono
Orono, Maine USA

1530-1540 "TOTAL TREE CHUNKWOOD AS RAW MATERIAL FOR FLAKE PRODUCTS"
Bruce Haataja
Michigan Technological University
Houghton, Michigan USA

1540-1600 "TIMBER HARVESTING, CONVERSION AND UTILIZATION IN THE FEDERAL REPUBLIC OF GERMANY: TECHNOLOGICAL TRENDS AND RESEARCH NEEDS"
J. Wippermann
Institute for Work Science
Vorwerksbusch, Federal Republic of Germany

1550-1610 Summaries of the following papers:

"THE SIMULATION OF FELLER/BUNCHER CHARACTERISTICS AFFECTING PRODUCTION IN PLANTATION THINNINGS"
Sharon Winsauer
Forest Science and Engineering Lab
U.S. Forest Service
Houghton, Michigan USA

Session F - Norman Smith, Presiding **(Hauck Auditorium)**
Professor and Chairman, Agricultural Engineering
University of Maine at Orono
Orono, Maine USA

1630-1730 Joint Address for COFE/IUFRO and ASAE

"ALTERNATING ENERGY SOURCES IN THE 1980's"
Robert A. G. Monks
U.S. Government
Washington, District of Columbia USA

(Evening) Cocktails and Lobster/Steak Banquet at York Commons (1830-2100)

Tuesday, August 14

(Morning and Afternoon)

Breakfast at York Commons (0600-0630)

0645-1800 Field trip to Great Northern Paper Company
Millinocket, Maine USA
Bart Harvey, Tom Wildman, Glenn Perkins, Bob Wright, Dan Boss, Bill Reardon, Ted Condon, and Ray Emery are our hosts

1) Energy From Wood Fiber or Computerized Road and Management Planning
2) Pulpwood Transportation and Handling
3) Picnic Luncheon (Courtesy of Great Northern)
4) Mechanization of Logging Systems
5) Catered Dinner in Millinocket (Farewell for ongoing Canada tour)
6) Departure for Woodstock, New Brunswick, Canada or Orono, Maine, USA

Wednesday, August 15 (for "USA only" participants)

(Morning)	Breakfast at York Commons (0645-0730)
0745-1200	Field trip to St. Regis Paper Company Costigan, Maine USA Dave Strathdee, John Doane, Bill Oliver, Al Beeson, and Larry Moffett are our hosts

1) Sawlog Hauling and Handling
2) Modern High-Speed Studmill
3) Wood Residue Recovery
4) Backhoe in Road Construction
5) Return to Orono, Maine, USA

Lunch at York Commons which ends "USA only" tour
Farewell for COFE/IUFRO in Maine, USA (1200-1300)

Tuesday, August 14

(Evening) Arrive at Woodstock, New Brunswick by bus in the evening following the study tour in central Maine. Check into motel for stay of two nights (Panorama and Wandlyn). Note that Atlantic Daylight Time is one hour ahead of Eastern Daylight Time in Maine.

Overnight 14/15 - Woodstock

Wednesday, August 15 - Study tour of operations for conifer species, hosted by Fraser Inc.

(Morning)

0600-0700 Breakfast in motels

0700-0815 Brief description and slide presentation to introduce Fraser Inc. at Panorama Motel.

0815-0945 Travel by bus from Woodstock to Plaster Rock.

0945-1000 Coffee at Plaster Rock Division of Fraser Inc.

1000-1100 Study mobile cross-cutting and private road delivery operations, mechanical maintenance facilities, and sawmill.

1100-1130 Travel by bus to Nictau forest airfield.

1130-1200 Demonstration of aerial water bombing for forest fire suppression by New Brunswick Department of Natural Resources.

1200-1330 Box lunch at airfield

(Afternoon)

1330-1430 Study fully mechanized tree harvesting system using feller-forwarders and sliding-boom delimbers.

1430-1630 Study site preparation techniques, effects of herbicide treatments, and plantations (3 to 6 years).

1630-1830 Travel by bus to York's Dining Room at Perth-Andover, New Brunswick.

1830 Dinner at York's Dining Room followed by return to motels in Woodstock.

Overnight 15/16 - Woodstock

Thursday, August 16 - Study tour of operations for deciduous species, hosted by Valley Forest Products Ltd.

(Morning)

0700-0800 Travel by bus (before breakfast!) to Pokiok Sugary. (Those with automobiles will drive to Pokiok parking area and not return to Woodstock.)

0800-0930 Introduction to Valley Forest Products Ltd.
- Lumberjack breakfast
- Poster and information session pertaining to the study tour.

0930-1145 Study feller-forwarder and portable chipper system, reclaiming fuel from forest biomass, and road construction by excavators.

1145-1245 Study cleaning of young stands comprised of several deciduous species.

1245-1315 Box lunch at red pine stand.

(Afternoon)

1315-1415 Study conventional forest operations systems using motor-manual felling and choker wheel skidding, cross-cutting, and delivery.

1415-1445 Study conventional road construction.

1445-1530 Study site preparation where ground roughness conditions are adverse.

1530 Travel by bus to King's Landing Historical Settlement. Areas of interest: water-powered sawmill, horse-powered fuel wood saw, musket shooting, King's Head Inn, woodboat, and Settlment activities. Dinner and entertainment followed by travel to Tibbits Hall residence at University of New Brunswick.

Overnight 16/17 - Fredericton

Friday, August 17 - Invited paper and voluntary poster sessions in Dineen Auditorium, Head Hall, University of New Brunswick (UNB) (following 0730 breakfast in Lady Beaverbrook Residence).

0900-0910 General Chairman - Per O. Nilsson
Swedish University of Agricultural Sciences
Garpenburg, Sweden

0910-0920 Welcome to UNB - John Downey, President
University of New Brunswick

Session 1 Tree harvesting working party. Chairman and theme paper
0920-0935
J.J.K. Spiers
New Zealand Logging Industry Research Association
Rotorua, New Zealand

0935-1010 "RECENT OFF-ROAD VEHICLE DEVELOPMENTS IN SWEDEN AND FINLAND"
Esko U. Mikkonen
Metsateho, Soumen Metsaeteollisuuden
Helsinki, Finland

1010-1035 **Poster display** off Lobby in Room C-11
Coffee and fruit in Head Hall Lobby

1035-1110 "FOREST OPERATIONS IN NORTHERN CHINA"
Li Guangda
Northeast College of Forestry
Heilongjiang, Peoples Republic of China

1110-1235 "THE FELLER-FORWARDER CONCEPT FOR TREE HARVESTING"
John Kurelek
Brantford, Ontario, Canada

Lunch At Lady Beaverbrook Residence for Delegates. It is recommended that visitors purchase lunch in the Student Union Building.

(Afternoon)

Session 2 Processing working party. Chairman and theme paper
1300-1315
Rolf Grammel
Univsitaet Freiburg
Federal Republic of Germany

1315-1350 "CENTRALIZED TREE PROCESSOR SYSTEM FOR OPTIMIZING THE VALUE OF OUTPUT PRODUCTS"
C-G Wachtmeister
Domanverket
Linkoping, Sweden

1350-1425 "TOPLESS FULL TREES AS INPUT MATERIAL FOR CENTRALIZED TREE PROCESSORS"
Karl Kwasnitschka
Furstlich Furstenbergische Forstdirektion
Federal Republic of Germany

1425-1450 **Poster session** in Room C-11.
Coffee and fruit in Head Hall Lobby.

Session 3 Delivery working party. Chairman and theme paper.
1450-1505
Magnus Larsson
Skogsarbeten
Spanga, Sweden

1505-1540 "RATIONALIZATION OF WOOD DELIVERY BY ROAD, RAIL AND WATER IN SOUTHERN FINLAND"
Reino E. Pulkki
National Board of Forestry
Helsinki, Finland

1540-1615 "CONTROL OF WOOD DELIVERY AND ASSOCIATED WOOD INVENTORY IMPLICATIONS IN NEW ZEALAND"
John E. Galbraith
New Zealand Logging Industry Research Association
Rotorua, New Zealand

1615-1650 "FOREST ROAD DESIGN AND NETWORK PLANNING IN JAPAN"
Yasushi Minamikata
University of Tokyo
Tokyo, Japan

1650-1800 Session conclusions, Per O. Nilsson

1800 Depart from Tibbits Hall by bus for informal outdoor barbeque at agricultural experimental farm.

Overnight 17/18 - Fredericton

Saturday, August 18 - Invited paper and voluntary poster session in Dineen Auditorium (following 0730 breakfast in Lady Beaverbrook Residence).

(Morning)

0830-0840 General Chairman - Pentti Hakkila
Finnish Forest Research Institute
Helsinki, Finland

Session 4 Stand establishment working party. Chairman and theme paper
0840-0855 Lorne F. Riley
Canadian Forest Service
Sault Ste. Marie, Ontario, Canada

0855-0930 "INTERACTION OF HARVESTING AND STAND ESTABLISHMENT IN HARDWOODS IN EASTERN NORTH AMERICA"
John C. Lees
Maritimes Forest Research Centre
Fredericton, New Brunswick, Canada

0930-1005 "INTERACTION OF HARVESTING AND STAND ESTABLISHMENT IN CONIFERS IN EASTERN NORTH AMERICA"
Maxwell L. McCormack
University of Maine
Orono, Maine, U.S.A.

1005-1030	**Poster session** in Room C-11 Coffee and fruit in Head Hall Lobby
1030-1105	"INTERACTIONS OF POST-ESTABLISHMENT STAND TREATMENT ON HARVESTING IN THE EUROPEAN EXPERIENCE" Staffen Berg and S.O. Andersson Forskningsstiftelson Skogsarbeten Spanga, Sweden
1105-1140	"INTERACTIONS OF HARVESTING AND STAND ESTABLISHMENT IN CONIFERS AND HARDWOODS IN THE EUROPEAN EXPERIENCE" Willem Heij Agricultural University Wageningen, The Netherlands
1140-1150	Session conclusions, Pentti Hakkila
1150	Official closing of the Symposium COFE - Thomas J. Corcoran (USA) IUFRO - THomas C. Bjerkelund (Canada)
Lunch	Delegates in Lady Beaverbrook Residence Visitors in Student Union Building
(Afternoon)	
1400-1530	IUFRO planning meeting, University Club, 3rd floor, Old Arts Building Division 3 Coordinator Marten Bol (The Netherlands) presiding
1530-1630	Informal hour at University Club
	Overnight 18/19 - Tibbits Hall available on request.

SYSTEMS ENGINEERING: A MAINE PERSPECTIVE
A PREFACE

In the State of Maine with more than 90 percent of the land area forested, the economy is heavily dependent upon the forest products industry, and the pulp and paper industry in particular. Approximately 97 percent of the forest land is under private ownership with half owned by industrial firms. It is not uncommon, in Maine, for firms to control large tracts of land--one firm controls nearly 2.5 million acres of land.

The large land owners control extensive tracts of land in mostly undeveloped parts of the state. Access to these tracts is limited and requires careful planning and costly road building. The situation has been further complicated with the onslaught of the current spruce budworm epidemic which is devastating the spruce and fir resources--a major component of the state's forest resource. Methods of controlling the epidemic, including application of aerial insecticides to reduce the insect populations, frequently are clouded by controversy. In addition, such control measures are costly and require constant monitoring of the project to insure the measures remain economically feasible.

Government regulative bodies have restricted some forestry activities. Heavy equipment and harvesting activities may not be permitted near some bodies of water or designated wildlife zones. Logging road construction is also restricted and must conform to standards prescribed by the State of Maine Land Use Regulation Commission.

The economic environment, in which forest products industries operate, must be considered in the planning of harvesting operations. The prior recession, of which the forest products industry has not yet fully recovered, increased inter and intra industry competition. Economic conditions have forced forest products industries to closely monitor costs to remain competitive, and has lead to reexamination of marginally productive operations and practices. A greater emphasis is placed on costs, which must now be monitored throughout the entire production process--from the land to the standing tree to the final product.

The changing environment, in which the forest products industry operates, has increased foresters' need for information which is necessary to plan efficiently to insure wood supplies meet both short and long term demands at a cost that is advantageous to the organization, yet within the confines of the law.

More information than previously collected is now necessary for effective decision making. But information is meaningless unless it can be systematically collected, stored, and retrieved in a manner that will add value to the decision making process. Planning of forest operations may utilize information regarding: inventory--the volume and quality of presently standing timber and expected inventories of future forests; soil and topographic conditions; harvesting costs; road construction costs; supply required to meet projected production requirements; location of supply with respect to established (or potential) markets; and areas which may be inaccessible or restricted. It would be very naive to suggest that this is the only information required for effective forest management, but even this partial list is not used by most forest product industries. The types of information suggested above are costly to obtain and difficult to store and retrieve quickly. Fortunately the computer facilitates the storage and retrieval aspects of the problem, but it does not make the data collection process any less costly.

Integrated systems design, database management, and user friendly systems, while familiar to many foresters, represent terminology changes resulting from computer usage and indicates the direction in which forestry is heading. System design allows the forester to collect and integrate different types of information so that they may be used in the in the planning of forest operations. For each type of data, a sub-system is designed that is tailored to make maximum use of the data collected. Foresters within the organization can access the databases that will aid in the decision making process. For example, individuals concerned with road construction can access the forest inventory database to locate overmature timber that must be harvested in the near future. Thus by accessing other databases decisions can be made indicating the optimum location of roads by combining data on soil and topographic conditions, current road locations and quality, market locations, and transportation times and costs that would be expected on the proposed road network.

Currently in Maine, the systems approach to information and information gathering is underway by several of the major landholders (and being considered by others). Not all of the sub-systems have yet been designed and implemented into the overall system, but remarkable strides are being made. Forest inventory data has been in place for some time, and road network data is currently being implemented. The system once fully operational will provide the forester with a hedge against the uncertainty with which organizations in the dynamic business community operate.

Effective and efficient information systems will be necessary if forest products companies are to remain competitive in the future. The shift from more traditional harvesting research to information based research is reflected by the increasing number of papers presented on this subject.

It was the intent of the COFE/IUFRO 1984 Conference to provide a forum in which information regarding research activities of forest organization could be exchanged. Like the systems design described above, the information obtained by each research organization differs, but the forum provides a means of gathering this information and distributing it to those foresters who find the information of great value in their research activities. It is also an indicator of the direction forest engineering research is heading and the needs that this research attempts to satisfy.

At the conference numerous papers and posters were presented indicating the direction and accomplishments of current research activities. In addition, field trips in Maine and New Brunswick provided an opportunity for the attendees to investigate first hand the environment in which forest product companies in northeastern North America operate. Excursions to Acadia National Park and Fort Knox offered a casual view of the region's natural beauty.

The COFE/IUFRO 1984 Conference would not have been possible without the cooperation and support of many organizations and individuals. Space and fear of omission does not permit thanking everyone individually. The following entities do desire recognitions: the Canadian/American Faculty Exchange and Enrichment Program, for partial financial support; Great Northern Paper Co., St. Regis Paper Co., Fraser Inc., Valley Forest Products Ltd., and New Brunswick Department of Natural Resources, who sponsored and hosted field trips; the staffs of the University of Maine at Orono and the University of New Brunswick, who organized and hosted the conference; authors and poster presenters, who shared their research activities; and the attendees for their attention, astute observation, and probing questions. Following is a permanent record of the information exchanged during this conference.

T.J. Corcoran
D.R. Gill

WELCOMING REMARKS

Gregory N. Brown

The faculty and staff of the College of Forest Resources, host for the University of Maine's component of the meeting, are pleased to welcome all participants to the Council of Forest Engineering/International Union of Foresty Research Organizations, Division 3, Conference, and to the University of Maine and the State of Maine.

The College of Forest Resources, University of Maine, is one of the oldest academic forest resources' programs in the United States, tracing its roots back to 1903. Until 1907, foresty was a department represented by a single faculty member (S. N. Spring, 1903-1905 and G. E. Tower, 1905-1907) and housed in the College of Engineering. In 1910, John M. Briscoe was appointed Department Head and the unit expanded such that by 1923 it had three instructors. A permanent location for the field camp was offered in 1931. Following Briscoe's death in 1933, Dwight Demeritt became Department Head from 1934 through 1946. Early in his tenure, the Cooperative Wildlife Research Unit was established, and shortly thereafter the first Master's degree was offered in Wildlife Management. The University of Maine also became one of the first universities to have an accredited forestry program during Demeritt's tenure, and the 1700-acre University Forest was obtained. In 1946, R.I. Ashman became Department Head and remained in that position until his retirement in 1957. During his tenure, in 1953 the first Master's degree was offered in Forest Management. In 1958, forestry became a school and Albert D. Nutting became its first Director. Nutting was instrumental in passage of the McIntire-Stennis legislation, working extensively with Maine's Congressman Clifford McIntire and Dean Winthrop Libby. During Nutting's administration, the current foresty building was completed in 1968 and named after its Director as Nutting Hall. The School was renamed the School of Forest Resources that same year. While the forestry curriculum began in 1903 and the wildlife curriculum in 1935, in 1960, options for students were expanded in the Forestry Curriculum. In 1968, the School was authorized to provide a two-year degree in Forest Management Technology, and by 1970 a Ph.D. in Forest Resources became available in the School. Director Nutting retired in 1971, and in 1972 Fred B. Knight became the Director. Under his administration, two chaired professorships were developed in the School. Also, in 1972, a B.S. degree in Forest Engineering, and in 1974, a B.S. degree in Recreation and Park Management, were approved. The Forest Engi-

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Greg Brown is Dean of the College of Forest Resourses, University of Maine, Orono, Maine, U.S.A.

neering program is one of only two forest engineering programs in the United States to be accredited by both the Society of American Foresters and the Accreditation Board for Engineering and Technology. During Dr. Knight's administration, the Cooperative Forestry Research Unit was formed in 1976 and is supported by forest landowners in the State of Maine. The faculty in the College of Forest Resources are involved in research activities, many through the Maine Agricultural Experiment Station, as well as teaching activities, and the College, through the Cooperative Extension Service, has an Extension program in forest resources. Under Dr. Knight's administration, in 1982 the School became the College of Forest Resources, and in 1983 Gregory N. Brown was appointed Dean. In 1984, the new College restructured into thre departments--Forest Biology, Forest Management and Wood Utilization, and Wildlife--each with a department chairman. An Associate Dean's position also was added. Subsequently, a new baccalaureate curriculum in Wood Technology was offered, and a separate Ph.D. in Wildlife was made available. Late in 1984, the baccalaureate program in Recreatin and Park Management was transferred totally to the College of Forest Resources. Also during 1984, a third chaired professorship was filled in the College, and a search was begun for a fourth chaired professorship. As a College, Forest Resources now shares equal administrative status with the other six colleges on the Orono campus of the University of Maine.

Forest resources provide the largest industry economically and play a central role in the lifestyle in the State of Maine. Maine covers an area of slightly over 21 million acres with approximately 90 percent of this area under forest cover. Forestland ownership is close to 95 percent private, with this private forestland divided about equally between industrial and nonindustrial ownership. Spruce/fir is the major forest type in land area covered, followed by northern hardwoods. Balsam fir is the predominant conifer with red maple the major hardwood. All forest amenities, including timber, wildlife, recreation and watersheds, receive major attention in the management of Maine's forestlands. Given this environment, the University the University has identified the College of Forest Resources for future growth. Today the College is one of the largest and strongest academic forest resources' programs in the world, and claims one of the largest bodies of active professional alumni, many having achieved highly visible positions in the profession.

During this conference, you will hear from many highly competent technical speakers in forest engineering. We hope that during the next few days you will enjoy your stay at the University of Maine at Orono as well as gain technicaal information during the conference.

THE CHANGING FOREST PRODUCTS INDUSTRIES

Benjamin Slatin

The future demand for the products of the forest products industries - lumber and wood products plus paper and allied products - will be strongly influenced by the impact of major changes in its present and potential markets. One major force for change is the integrated circuit on a computer chip. This is changing the way business and consumers process, store, distribute, and receive all types of information, as well as the way business produces its goods and services. These and other changes now occurring are different in kind from those of the past three decades, although these also, as the report shows, have had major impact on the demand for the products of the forest products industries.

Introduction

I would like you to consider **change** as the keynote to this meeting. Not change in general--that is a fact of life--but the impact and challenges of changes in today's markets and business environment as they affect the forest products industries.

The forest products industries include both the lumber and wood products industry (SIC code 24) and the paper and allied products industry (SIC code 26).[1] In terms of wood, the paper and allied products industry accounts for about 30% of the total wood used in the United States each year.[2] The value of lumber and wood products shipments is presently at an estimated $55 billion per year, while shipments of paper and allied products are running at a rate of $94 billion per year.[3]

The forest products industries have always known change. Up to the decade of the 1980's, these changes have generally had a positive impact, leading to increases in demand for the products of both the forest products industries. This was not an automatic process, but rather reflected the reaction of these industries to the ongoing technological and market changes, leading to the development of new products and investment of rather large sums of money for new plant and equipment.

The revolutionary changes occurring in today's technology and today's markets are, it seems to me, of a different order of magnitude than those of the first three decades

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following World War II. In that earlier period the impact of the changes tended toward creating new markets for the forest products industries as well as new products that were in direct competition with the products of these industries. The impact of these changes could be resolved--for better or worse--by normal product development and marketing research.

Today's changes are resulting in completely new ways of doing business, as, for example, changes in the types of structures built such as to have major impact upon the demand for wood or, in the case of paper, changes in the processing, storage and distribution of information that could have major impact upon the volume and types of paper required. For both industries there have been long-term changes in the way wood fiber is being used, as for example, plywood, flakeboard and particleboard, oriented strand board in the lumber and wood products industry; chips from the previously-considered waste products of the wood products industry; increased use of recyclable paper or, as it was once known, waste paper and the growing use of hardwoods in the paper industry.

Computer technology as presently being developed is an entirely new motivating force in the wood products industries, as indeed, in the entire economy. On the supply side, computers control in both the manufacturing and distribution of the products of these industries. It is a major tool in Research and Development. On the demand side, there is not only its potential impact on the demand for printing papers and newsprint, but also potential changes in all the markets. Computer technology is changing the way America does its business and the very product it buys.

These by no means exhaust the major changes taking place in today's economic environment. The pulp, paper and paperboard sectors of the forest products industries are highly capital intensive. In terms of total assets per employee it ranks high among U.S. industries.[4] The lumber and wood products industries, while less capital intensive, are dependent upon long-term investments in woodlands; the time from initial investment to profit realization is usually measured in decades, not years. The high interest rates of the past few years offers a serious challenge to the future growth.

Even that is not all. Countries all around the world are developing forest products industries that are highly competitive with those in the United States. While it is true that the forest products industries of the United States are among the most efficient in the world, and that world demand for the products of these industries is continually rising, international competition today is quite different from that of the previous decades.

I should like to review with you briefly, the types of changes of this nature that have occured in the past thirty years and trace their impact on the demand for the products of the forest products industries. I will try to contrast these with the types of technological and marketing changes that are occurring today, and trace the economic impact of these changes on the demand for the products of our industries and on the raw materials required.

I can tell you now that I do not feel the economic and technological environment of the Nineteen Eighties and Nineteen Nineties is necessarily inimical to the forest products industries. Rather, it offers challenges and opportunities that could well lead to new growth. As those responsible for care of the forests--the basic raw material of the forest products industries--you will have an important role in the resolution of these challenges and opportunities.

The Nineteen Fifties

Let us start with the nineteen-fifties. I do not mean to make this a nostalgia trip, but from today's vantage point the economic problems of the fifties do seem somewhat less intractable than those of today.

The nineteen-fifties was a decade of rebuilding: families, businesses, homes, even entire nations. For the wood products industries, the growth in family formation was particularly important: the total grew by 5 million, representing an important element in the demand for new housing.[5] At the same time, the huge volume of savings accumulated during World War II became a huge reservoir of mortgage funds. Interest rates generally, and mortgage rates in particular, were low. The Federal Government assisted; the Veterans Administration, for example, guaranteed loans in the 4% to 5% range.

During the nineteen-fifties nearly 1.2 million new housing units were started, on average, each year.[6] Single family homes, made largely from wood, predominated. A new credit instrument--the amortized mortgage--permitted the buyer to pay off the mortgage by a fixed amount each month for a period usually of 20, 25, or 30 years, making new homes affordable to the millions of young veterans of World War II. The baby boom remained with us through the entire decade, and the average size of the home grew larger and larger.

While it did not seem particularly low at the time, consumer prices were rising at only 2.3% per year, while wholesale prices (now called by the more accurate term, producer prices) rose at a 1.8% per year average. Unemployment was low--averaging about 5%--while average earnings of production workers increased, on average by 5.6% per year, and by 1959 reached the record-high of $2.02 per hour. It was an exciting period, when total economic growth, as measured by the real gross national product, was 3,4% per year.[7]

The paper industry found an equally friendly environment. New markets were increasing. This was the time when the U.S. distribution systems changed from small retail stores to supermarkets, and these supermarkets required their products to be packaged in a form that would not only be easily sold to customers, but would actually become an important part of the selling effort through attractive and eye--catching design. The introducton of frozen foods offered yet another method of distribution, requiring unique specifications for the package. The need for shipping containers for such products as fertilizer and cement opened additional new markets.

Paper and paperboard proved to be the answer to all these developments, and demand grew apace. The fiber box, made from linerboard and corrugating materials, the cartons made from recyclable papers and from bleached kraft wood pulp (initially largely for frozen foods), together with the paper bags and sacks used in retail stores and paper shipping sack for agricultural, chemical, minerals and other products became the major packaging and shipping products of the decade.

The computer and copier were introduced in the middle of that decade, but gave only a promise of their potential as markets for paper and paperboard. At the same time, television was offering strong competition in the advertising markets served by newspapers, magazines and commercial printing [8], but use of printing papers was so widespread throughout the economy that these sectors also enjoyed strong growth.[9]

This was also a period when use of chips from the wood products industry became an important source of fiber, and when several of the wood products companies, recognizing the importance of fully utilizing the output of their forests, bought or built pulp and papermaking facilities. At the same time, other types of companies, such as those in other lines of packaging products, also entered the pulp and paper industry.

The Nineteen-Sixties

Where the nineteen-fifties introduced a completely different economic environment from that of the nineteen-thirties, the nineteen-sixties were more simply an extension of the fifties. A major difference, particularly in the first half of that decade, was the rate of growth. In terms of real GNP, growth averaged a breathing 4.4% per year in one long cyclical upswing (purists say it actually ended in 1966, but technically 1967 was not a recession period).[10]

The nineteen sixties was a decade of social change--the New Society and the Great Society--and this had a strong impact upon the economic environment. Nonetheless, the growth in average hourly earnings of production workers actually slowed from that of the nineteen fifties, to 4.3% per year, while the growth in consumers' prices held to 2.4% per year, and that of producer prices 1.3% per year. Unemployment remained relatively low; ending the decade at 3.5% while new family formation--that key variable in the demand for new homes--totalled 5.6 million between 1960 and 1969.

In this type of economic environment housing starts increased to an average of nearly 1.5 million per year, ranging from a low of 1.2 million in 1966 to a high of 1.6 million in 1963 and ending the decade with 1.5 million in both 1968 and 1969. While mortgage rates were higher than in the fifties, they were still affordable for a large part of the population. New houses continued to be larger and larger, with many purchasers buying second houses for vacation sites.

The paper industry responded well to the changes of the nineteen sixties. The packaging grades generally remained strong, although the introduction of plastic packaging products offered strong competition to paper merchandise bags, paper wrappings and certain cartons. Bulk shipping methods ate into the markets for paper shipping sacks, but the corrugated shipping container continued to find new markets as box makers engineered their containers to meet the specific needs of each market. Demand for printing papers also continued strong, with the growth of the office copier offering a major new market, while the rising number of computers resulted in major increases in the demand for computer printout papers and for punch cards--at that time about the only way to input data into the computer.[11] Toward the end of the decade the industry responded to the growing demand for paper and paperboard by installing a record-breaking 10 million tons of new capacity in the four years 1966 through 1969--a 20% increase from the 1965 level.[12]

The Nineteen Seventies, Nineteen Eighties and Beyond

The types of changes that occurred in the 1970's are the type that I am talking about: changes that completely alter previous ways of doing business. Immediate examples are the oil shocks of 1972 and 1979, which brought the price of petroleum from $3 to $30 a barrel and forever changed the world's energy-use patterns. For an energy intensive industry like paper, the impact was particularly severe. The industry responded: in eleven years it reduced its use of fossil fuel and purchased electric energy per ton of output by 34%.[13] If the effect of the requirements of energy for environmental use and for changes in the fuel mix is considered, the adjusted decrease was 36%. This was achieved largely by taking advantage of the energy contained in the industry's major raw material--wood and by moving away from fuel oil. In 1972 the paper industry obtained 21% of its energy from residual fuel oil; the 1983 ratio was 9%. In that same period, the industry increased its energy drawn from hogged fuel and bark from 6.5% to 15%, and energy from spent liquor (solids) from 33% to 38%. The lumber and wood products industry also responded to the impact of changing fuel oil prices by reducing its total consumption of fuel oil from 6.4 billion barrels in 1971 to 4.5 billion barrels in 1981 (the latest data available).[14] The National Forest Products Association reports that at present only 25% of the total energy consumed by the lumber and wood products industries comes from fossil fuels and purchased electric energy. For the paper industry, the ratio is about 46%.

The 1970's was also a period of heightened awareness of the affects of industrial pollution on the environment. Old mills had to be retrofitted to meet the new regulations; no new mills could be built without paying careful attention to its impact on the total environment. Both the paper industry and the lumber and wood products industry spent billions of dollars in this period to bring their mills and plants into compliance with the new regulations.[15,16]

There were major changes in the economic structure of the country as well. Total economic activity as measured by real GNP slowed down, partly as a result of the return of the business cycle. For the decade as a whole, that is from 1970-1979, real GNP rose at 3.5% per year. During this decade inflationary pressures increased: the average increase in consumer price index was 7.2% per year; in the producer price index 8.8% per year. Average hourly earnings of production workers rose at the unprecented rate of 7.4% per year. Unemployment rates began to rise and by the end of the decade was nearly 6%. At the same time family formation steepened, with the total increase from 1970-1979 amounting to 6.2 million families.

The forest products industries responded to these sharply rising cost pressures by instituting major programs aimed at reductions in processing costs. New mills tended to be larger, more capital intensive and far less labor intensive. Administrative and management policies were reviewed and procedures streamlined wherever possible. One measure of the sucess of this effort: in 1970 the pulp, paper and paperboard industries employed 290,000 persons, producing 52 million tons of paper and paperboard. Today, production is running at 68 million tons per year, while total employment amounts to 265,000 persons.[17,18]

For the most of the 1970's, interest rates were only moderately higher than they were in the 1960's, holding in the 8%-9% range for mortages. It was during the 1970's that housing starts soared to the 2 million level, with above 2 million starts per year recorded in 1971, 1972, 1973, and 1978, while the 1977 total was just a shade below the 2 million level. That pretty well marked the end of the housing boom; in the last years of the decade interest rates began a very steep rise, peaking in the early years of the 1980's at the unheard of 17%-18% range.[19] They have since come down considerably, but even today both short and long-term rates are extremely high by historic standards.

For capital intensive industries like paper and lumber, the impact is most challenging. Cash flow, reflecting the combined total of such items as profits, depreciation and deferred taxes, together with tax incentives from such legislative provisions as the investment tax and energy credits become more and more important considerations in evaluating future levels of capital expenditures.

The high interest rates of the late 1970's and early 1980's had a drastic impact upon the lumber and wood products industry. Production of lumber had fluctuated narrowly about 35 billion board feet per year for the entire period from 1947-1979, going no lower than 33 billion (1957 and 1958) and no higher than 38 billion (1972-1973).[20] Production dropped to 32 billion in 1980, 29 billion in 1981 and to a catastrophic 26 billion in 1982. However, production recovered to 32 billion board feet in 1983 and now is probably currently back to its pre-1980 average.

The decline in interest rates in late 1982 stimulated the housing industry, with starts moving back to the 1.5-2 million range in 1983 and continuing in that range even in the face of recent increases in interest rates.

In the paper industry, the market trends in the 1970's and 1980's were basically extensions of those of the 1960's. The computer and office copier fulfilled their early promise and demand for these types of papers rose sharply. More recently, there has been a return to demand for white papers used by magazines and commercial printers. At the same time, the impact of plastics continued to grow: flexible paper packaging materials, together with many types of paperboard cartons, continued to meet strong competition in these markets. The corrugated shipping container however, continued to be the prime shipping container for the nation's products.[21]

The early years of this decade also saw some major changes in the corporate structure of the paper industry. Two of the major packaging companies that previously entered the paper industry to complete their line of packaging materials reversed their thinking and sold off most of their paper and paperboard operations. At the same time some of the conglomerates that had entered the paper field to broaden their total market also moved out of the industry.

At the present time the nation is moving along the upswing of a major business cycle, and this has been a major force in bolstering demand for the products of the forest products industry. The paper industry in particular is presently operating close to full capacity in nearly all of its grades. In addition, there has been a strong reduction in the inflationary pressure evident in the previous five or six years. Increases in average hourly earnings of production workers moved down to the 4.5%-5% per year range, while increases in total producer prices fell to the 1%-2% per year range. These changes in the economic environment are not, however, much different from those of the past.

But there are changes taking place in the economy that are of a different order of magnitude from those that have occurred in the past thirty years. One, as noted earlier, is the integrated circuit on a computer chip. This is revolutionizing both the production and distribution processes in the American industry along with making drastic changes in the way in which information is processed, stored and distributed. Today no modern paper, paperboard or wood products mill can be built without extensive utilization of computer processing. The computer is also making major impacts on the way in which business tracks its own operations and controls its levels of inventories.

The huge increase in recent years in the number of personal computers at both the office and home has yet to make its full impact. It offers a potential for major changes in the way consumers and businesses secure information and even in the way they purchase goods and services. It is drastically changing the ways both consumers and businesses process and transmit information. It could change the way we spend our leisure time, including in particular, the reading habits of the nation. So far we still like the printed page.

Change, as we have seen, is the order of the day. But I believe the changes now occurring will require a complete rethinking of the business process. The potential changes are breathtaking. One scenario for example, sees a major decentralization of office work as executives rely more and more on computers and are able to do large parts of their work away from the office. The impact of such decentralization on building generally, and home building in particular, can at present only be left to the imagination. As far as paper demand is concerned, there is a scenario presently being envisioned of drastically reduced demand for paper. Other scenarios, utilizing the same data, see an ever-growing need for hard copy: as more and more data are processed, stored and distributed by electronic means, the needs for hard copy, while declining as a percent of total, results in increasing paper tonnage demand. Personally, I think the latter is more likely to happen.

I don't need to tell this audience how the growth and care of the forest is being drastically altered by the computer. There are computer models for almost every phase of forest operations. One major conflict about the future of the forest industries is whether or not the forest can grow enough wood to meet future demands and still be maintained on a sustained yield basis. The computer adds another dimension to scientific management, providing additional support to those who believe that proper forest management will permit growth to keep pace with demand in the foreseeable future.

Even aside from the computer chip, there are changes in the world economy that could have major impacts on the forest products industry. In the past 10 years for example, Brazil for one has greatly increased its production of wood pulp, utilizing the vast resources of its forests. There are trees in Brazil that come to maturity in about one-third or one-fourth the time of trees in the U.S. South and one-tenth the time trees in the North or in Canada do. The competitive potential, not only from Brazil but from other forest areas of the world which are presently largely undeveloped, will offer new challenges to the North American industry. The recent increases in the value of the dollar in many of the United States' major foreign markets has seriously affected its competitive position. While the paper and forest products industries rank among the highest in the world in terms of output per manhour and availability of wood, they have also been affected by these higher exchange rates. Yet even today U.S. exports of pulp and paperboard are high by historic standards.

The history of the United States' forest products industry has been one of successful response to the challenges of change. These challenges are becoming more severe and coming on much faster, but there is every reason to believe that the U.S. forest products industries will continue to meet them successfully.

FOOTNOTES

[1] **Standard Industrial Classification Manual.** Office of Management and Budget, 1977.

[2] **U.S. Timber Production, Trade, Consumption and Price Statistics 1950-1981.** U.S. Department of Agriculture Forest Service. Misc. Pub. No. 1424.

[3] The lumber and wood products estimates are based on the changes in price and volume since 1981, when the **Annual Survey of Manufacturers** reported the total at $46.8 billion. The paper and allied products data are currently reported by the Department of Commerce, Bureau of Census, in its **Current Industrial Reports, Manufacturers Shipments and Inventories and Orders**, released monthly.

[4] **The Conference Board.** Economic Road Maps, No. 1957, August 1983.

[5] **Current Population Reports, Population Characteristics, Households and Families by Types,** various issues. U.S. Department of Commerce, Bureau of the Census.

[6] **Construction Reports, Housing Starts.** U.S. Department of Commerce, Bureau of the Census, various issues.

[7] **The National Income and Product Accounts of the** U.S. Bureau of Economic Analysis, Department of Commerce.

[8] McCann-Erickson, Inc.

[9] **Statistics of Paper, Paperboard and Wood Pulp,** 1984. American Paper and Pulp Association.

[10] **Business Condition Digest.** Bureau of Economic Analysis, Department of Commerce.

[11] **Statistics of Paper, Paperboard and Wood Pulp,** 1972. American Paper Institute.

[12] **Paper, Paperboard and Wood Pulp Capacity,** 1965-1969. Annual Reports 1966-1969, American Paper Institute.

[13] **Paper Industry Energy Efficiency - First Quarter 1984.** Materials & Technology Group, American Paper Institute.

[14] **U.S. Pulp, Paper and Board Industry Energy Use -** Calendar Year 1983. Pulp, Materials & Technology Group, American Paper Institute.

[15] **A Survey of Pulp & Paper Industry Environmental Protection Expenditures, 1983.** National Council of the Paper Industry for Air & Stream Improvement.

[16] **Current Industrial Reports, Pollution Abatement Costs and Expenditures,** 1982. MA-200 (82)-1. Bureau of the Census, U.S. Department of Commerce.

[17] Employment data from Bureau of Labor Statistics, Department of Labor.

[18] Production data. American Paper Institute.

[19] **Federal Reserve Bulletin** (monthly). Bulletin of the Board of Governor of the Federal Reserve System.

[20] National Forest Products Association. **Fingertip Facts and Figures.** Also, **Business Statistics,** 1977. Bureau of Economic Analysis, U.S. Department of Commerce.

[21] **Statistics of Paper, Paperboard and Wood Pulp,** 1982. American Paper Institute.

BIBLIOGRAPHY

American Paper and Pulp Association. Statistics of Paper, Paperboard and Wood Pulp, 1984, 1982, 1972, 1964.

American Paper Institute - Pulp, Materials & Technology Group. Paper Industry Energy Efficiency - First Quarter 1984.

American Paper Institute. Paper, Paperboard and Wood Pulp Capacity, 1965-1969, Annual Reports 1966-1969.

American Paper Institute - Pulp, Materials & Technology Group. U.S. Pulp, Paper and Board Industry Energy Use. Calendar Year 1983.

Bureau of Economic Analysis, U.S. Department of Commerce.

Business Condition Digest.

Business Statistics, 1977.

The Conference Board. Road Maps for Industry. No. 1957, August 1983.

Department of Labor, Bureau of Labor Statistics. Employment and Earnings. Monthly Report, various issues.

Federal Reserve Bulletin (monthly). Board of Governor of the Federal Reserve System. Monthly Report, various issues.

McCann-Erickson, Inc.

National Council of the Paper Industry for Air & Stream Improvement. A Survey of Pulp & Paper Industry Environmental Protection Expenditures, 1983.

National Forest Products Association. Fingertip Facts and Figures, February 1984.

Office of Management and Budget. Standard Industrial Classification Manual, 1972.

U.S. Department of Agriculture, Forest Service. U.S. Timber Production, Trade, Consumption and Price Statistics, 1950-1981.

U.S. Department of Commerce, Bureau of the Census. Current Industrial Reports, Pollution Abatement Cost and Expenditures, 1982. MA-200(82)-1.

U.S. Department of Commerce, Bureau of Economic Analysis. The National Income and Product Accounts of the U.S.

U.S. Department of Commerce, Bureau of the Census. Annual Survey of Manufactures, 1981.

U.S. Department of Commerce, Bureau of the Census. Construction Reports, Housing Starts, various issues.

U.S. Department of Commerce, Bureau of the Census. Current Populations Reports, Population Characteristics, Households and Families by Types, various issues.

A BANQUET ADDRESS

Marten Bol

Ladies and gentlemen, one can look at forests and trees from different angles..

First there is a **cultural-historical** point of view. For instance, one can examine the development of forests and trees in the world since the Third Day of Creation and the specification (lack of) of species "in the beginning". In the travels of Abraham, who was very devoted to trees and to the holy land, he rested under an oak tree--probably a stone oak (*Quercus ilex*), the first **group** of trees, the oaks of Mamre, a forest. Forests probably covered 5.4 milliard (billion) hectare in those days. In the mean time this amount has decreased considerably with the appearance of man on the Sixth Day.

A second approach has to do with **holiness and symbolism.** The oaks of Mamre were situated at holy places. They contributed to holiness--maybe because of their image of sturdiness, constancy, and durability. We also find this viewpoint of trees and symbolism in many famous paintings in world history--for example, think of Jeroen Bosch.

Symbolism also exists with Noah building his ark from a very durable wood species, probably Cypressis (festigiata). As an illustration of durability, it was used for roofing in temples, as well as for coffins. It is remarkable that in literature, Cypressis is also known as the tree of grief and sorrow, and that it was used as a shelter tree on grave yards. Some of the paintings of van Gogh, around Arles in the Provence demonstrate this. Symbolism is derived from utilization and function.

A third view of forests and trees, a very important one, is the **biological and ecological** approach. This approach examines trees as part of a totality, ecosystem, or landscape. Such a view could have lead to the interwoven expressions of connection and union in art. Maybe the paintings of Ruysdael or some French impressionists are examples of that.

The ecological viewpoint of forests today draws a lot of attention again. I say **again,** because one can notice such interest in earlier times. In between, we had a period (or periods) with straight, rational, and economic thinking..

Marten Bol is Coordinator of IUFRO Division 3.

Nowadays, right or wrong, forestry is characterized with words such as clear-cutting, large scale operations, monocultures, etc.

In history, forestry and other forms of land use were always exposed to extremes--not unlike the extremes of a pendulum. Apparantly, it is difficult or uninteresting for human beings to dwell somewhere inbetween.

I have the impression that again today, at least in Central and Western Europe, the wind of change and alteration is going over our trees. Small scale, variety, group selection, cutting single trees, or cutting no trees at all are the subjects discussed.

I come to my fourth and final viewpoint of a forest, its trees, and parts of trees, and that is **function.** When functioning, trees transform water, carbon dioxide, and some minerals with solar energy into a structure that is beautiful and useful at the same time. The structure is represented by the shape of a tree with branches, retraced in a leaf with viens, or by the structure of wood and bark. Looking at proportions and fundamental rules, as Leonardo did and later on as did Mondriaan. Function and structure were with the spirit of the artists of applied art assembled in Bauhaus in Germany 1920-1925.

Of course I return now to forestry, forestry as an **integrated discipline,** based on ecological principles with forests **serving many functions**--including the world wood supply through the process of harvesting.

It is appropriate, I think, being in North America, to introduce the legendary giant, Paul Bunyan the lumberjack. Paul Bunyan felled and skidded many cubic meters of timber in the North American woods in the beginning of the century. His statue is situated here in Bangor, Maine. It is 31 feet high and constructed of glassfibre.

More than three centuries earlier, Francois Rabelais created his giant--Gargantua. Gargantua exploited the dense broad-leaved forests around Orleans. Today this region is one of the more fertile agricultural areas of France. Rabelais has his statue in bronze, in Chinon, his native town on the Vienne river.

I could mention additionally and more recently, the statue of the timber raftsmen in the Angerman River, Solleftea, Sweden. Maybe it is constructed in wood, I really don't remember. Strength, skill, and courage were appreciated in those days.

Mind you. I do not consider the harvesting methods of Paul Bunyan and Gargantua as appropriate one's for today. They could have been more respectful to the soil and the vegetation, and to the forest regeneration and the environment. Therefore, I leave them now with their mosquito's in the Eastern border area of the United States and Canada, and in the plain of Beauce to the South of Paris. By the way, I stressed the point of a possible connection between the two at an earlier event.

Harvesting should be a phase in the **continuing** process of forest growth and development. Nevertheless, harvesting means an intervention, no matter how carefully executed, an intervention in the forest ecosystem. To quote the Flemish author Louis Paul Boon: "If you want to make an omelet you will have to break the shells." Additional an more important questions, of course, are:

> How many eggs do you want in your omelet?
> And secondly, what to do with the shells?

It is a challege to all of us as members of IUFRO Division 3 or COFE to not only provide the world with wood--"where no wood is, there the fire goes out (Proverbs 26:20)"--but also to limit the determental side-effects of harvesting and to deal with regeneration and establishment, with planning and control, and with forest labor. The wish to minimize costs, to raise productivity, means an extra field of tension, and asks for extra efforts to solve problems.

I hope, and I am sure, that this meeting will be inspiring in this sense.

Ladies and gentlemen, I am grateful that this meeting can be held in North Eastern America. We owe a great debt of gratitude to the University of Maine at Orono and to the University of New Brunswick, Canada, our hosts. In particular I would like to mention Professor Thomas Corcoran, USA, and Professor Thomas Bjerkelund, Canada, who organized this meeting in such an excellent way. I would also like to include in my words of thanks Mrs. Myrna Corcoran and Mrs. Marjorie Hoffman, for their efforts to make this conference so successful.

Finally, I would like to mention the Council on Forest Engineering. We as IUFRO Division 3 appreciate the cooperation established with this organization during this meeting very much. And maybe this meeting will contribute to making COFE well-acquainted with forest research institutes in other parts of the world, in favor of our mutual interest.

Ladies and gentlemen, I am convinced that we have remarkable days in front of us.

TREE HARVESTING

J.J.K. Spiers

Abstract - This, the Tree Harvesting Working Party (3.01.01) of IUFRO's Division 3, covers off-road tree harvesting operations from the stump to the truck road. It embraces felling, delimbing, extraction, processing and segregation. This session explores some parameters in reviewing research and development in these areas.

There is a tendency to see full mechanisation as the ultimate in tree harvesting. In fact, one country had as a stated policy objective "to achieve a situation where there was no man on the ground and no hand on the wood". Such objectives may not be appropriate in many regions or even in most countries of the world. In setting policy or strategic objectives or specific region, the following factors in any country need to be taken into consideration :

Economics

The value of wood and the relative costs of labour and machines differ widely from country to country. An understanding of these relativities must be a prime consideration in selecting systems or components in each system.

Environment

Not only do the physical factors of terrain existing in any forest area affect man and machine performance in the short term, but the ecological relationship between them and the harvesting system influence soil, water, recreational and aesthetic values. A balance must be achieved between profitable productivity in the present and desirable land management in perpetuity.

[1]Paper presented at COFE/IUFRO - 1984 Fredricton, New Brunswick, Canada,17-18 August.

[2]J.J.K. (Jim) Spiers has been Director of the New Zealand Logging Industry Research Association, Rotorua, New Zealand from 1975-1983.

Human Resource

The availability, level of knowledge and training of the workforce must influence selection of the system and their health and well being be considered in selecting components of it.

This all adds up to choosing an appropriate technology in selecting a harvesting system. The three papers presented in this session indicate the wide technology spread in only one zone of the world. The north temperate region influenced by continental climates. Admittedly, most of the world's roundwood production originates from this zone but in other regions quite different conditions prevail.

To assess the value of a technology for a particular country or region, it is desirable to set some appropriate type of baseline. It would seem that the widely used manual or motor-manual methods in most cases would serve as such a baseline. I will try to illustrate this approach with an example from Australia, where a number of large companies are introducing mechanisation of felling, delimbing and processing in Pinus radiata plantations.

The first step is to set a baseline for cost of production taking into account tree size or whatever other factors are considered significant as an influence on cost of production. The solid line on Figure 1 indicates cost per cubic metre to fell and delimb and cut to length with a man and a powersaw.

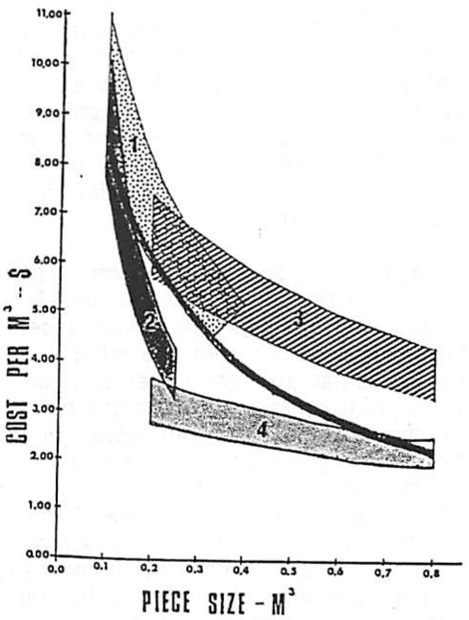


Fig. 1

The next steps indicate the results achieved with a variety of machines developed for felling, delimbing, processing, or a combination of these which have been tested over the past few years.

Curve 1 shows a harvester which stroke delimbs the standing tree, tops, fells and bunches.

Curve 2 shows a harvester which fells, has continuous roller feed delimbing and aligns wood for extraction.

Curve 3 shows a stroke delimber processor which is forwarder mounted.

Curve 4 shows a stroke delimber processor which is excavator mounted.

The broad banding of each curve recognises that the actual performance of these machines varies according to the environment they are working in, the management of the operation and the operators themselves. These curves are calculated on a single shift basis. On a multiple shift basis most would look even better in comparison with the baseline.

The foregoing are the results of comparing existing technology. It is much more difficult to predict results from machines that are under development, although this is something that obviously the designer must attempt.

Over the past ten years, a significant amount of development has occurred in tree harvesting mechanisation. Mostly that has happened in two regions of the world characterised by small trees on relatively easy topography but often difficult ground conditions. Over this past two decades particularly the development has been a process of evolution and survival of the fittest, particularly here in Canada. This session's speakers should also illustrate aspects of new developments. I believe we need to take into consideration some of the following points in the subsequent discussions.

There has been considerable argument over the respective merits of single- versus multi-function machines. Development action appears to have been cyclic with one or the other concept being popular at a particular time or in a particular region. Basically, the argument could be summarised that single-function machines in phased operation gave better system utilisation, particularly in that if one machine in the system broke down the operation still continued. The argument in favour of multi-function machines have centred on the gains, both environmentally and economically, inherent in one chassis, one machine pass and one operator rather than several.

Undoubtedly, to achieve advances in mechanisation,reliable and effective components are essential. For tree harvesting,component design, as far as possible, should be simple, rugged and matched in the relationship of power output and stress with the other components in the machine. Advanced metallurgy, improved hydraulics and an exciting new world of electronics have enabled significant advances to be made.

The relationship between the machine and the terrain is vital. Logging poses extremely difficult engineering problems. It is encouraging to see advances being made at present in new tyre and track configuration and that an interesting series of new machines with different concepts of all terrain chassis are starting to be applied in more difficult topography.

The compatibility of machine to operator is now better understood and the relationship of comfort and control functions to operator health and conceptual functioning is being taken into consideration in machine design. Not only are the machines now easier to operate, they are more acceptable ergonomically. The machines may have reduced the incidence of traumatic accidents in the tree harvesting system, but the possibilities of long-term injury to the central nervous system cannot be neglected. With regard to the control function, computers are being applied, particularly in multi-function machines. The industry is on the way to automation and robotics and remote control are reasonable possibilities. But, you cannot disregard the fact that we haven't a robot in that machine, we have a man; and as well as his physical well being, his interest and motivation factors must be maintained at a high level.

Lastly, in assessing the impact of a new machine developed to undertake one or more phases of the harvesting operation, its potential for greatly increased productivity in that phase must be kept in perspective in the harvesting system. A new unit introduced to the system may have greatly increased productivity potential over its predecessor and this potential can be multiplied by shift work. However, a unit must be seen as part of a system. If it is a later phase of the system, can the wood be kept up to it or, when used at full potential, can a significant increase in production be handled by the succeeeding machines, the transport systems and even the mills. In many timber sales, there are restrictions on productivity posed by availability of wood or quotas, which may preclude the potential of one part of the system being fully exploited. Highly mechanised systems need effective skilled management.

CENTRAL TREE PROCESSING[1]

R. H. Grammel[2]

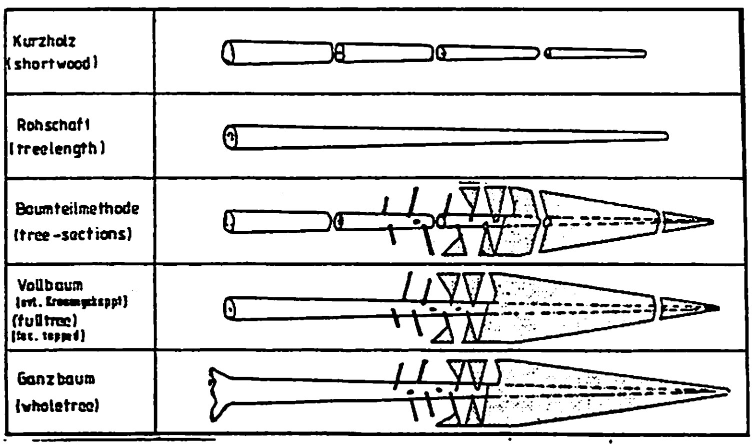
BASIC DEFINITION

The central processing of trees is based on the fundamental concept of shifting harvesting tasks as far as possible from the forest to a permanent processing installation. These installations are called woodyards and can be run by:

- private forest-owners
- independent contractors
- forest industries (often in combination with sawmills and other wood industries)

The qualities of the central processed trees depends on the status and size of the forest, the quality of trees in the forests, terrain, transport conditions, etc. A big influence on the technique of central processing are the requests by the customers.

The following forms are processed at woodyards:



depending upon the degree of processing and on marketing conditions:

- concentration of raw materials. The material is brought to a central installation to take advantage of the efficiencies of mass production.

- processing, i.e. delimbing, debarking, etc. It is important to note that permanent processing installations require less repairs, save energy, and are generally more efficient.

- sorting, with the aim of determining outer and long-termed inner wood qualities automatically in order to maximize the value of the wood products.

- marketing (or distribution): The wood is sold at the woodyard, where bills are written and statistics are gathered automatically. (Distribution, if central processing is done by the timber-industry.)

Delimbing, debarking, and sorting into different classes are normally the main functions of the tree-sections- and full-tree- methods of processing. Characteristically, European woodyards sort wood into more than 60 bins.

IMPORTANCE AND TRENDS OF CENTRAL PROCESSING

The Joint Committee FAO/ECE/ILO at the 15th Session in Izmir/Turkey in 1984 (TIM/EFC/BP. 1/14, Geneva) tried to get an overview of the significance and extent of the question of "location and methods of primary roundwood conversion."

B. Akre said that for the Scandinavian countries - Denmark, Finland, Sweden and Norway - the importance of central wood processing is limited. In Sweden and Norway less than 2% of the total harvested wood is brought to processing terminals. In Finland and Denmark, the system is used even less. Akre's prognosis is that by the year 1990 the use of the tree-sections method will increase to 5 - 6%, meaning that the trees will be delimbed and debarked at the woodyards. Use of this processing method will provide the opportunity of gaining energy from the wood waste.

P.F. Abol (USSR) spoke for the USSR and the East-European countries. He said that only 3% of the wood in the USSR is processed using the log-length method. At least 6% of the wood is carried to the woodyards as full-trees and about 90% as tree-lengths. The tree-length-method is popular, since the trees must be transported by trucks, railways, and ships for long distances between the woodyards and destinations elsewhere. In East Germany, Poland, Hungary, Romania, and Bulgaria, the log-length method is used and the processing takes place in the forest stands. In Czechoslovakia, tree-length processing is used more often.

In the USSR, some woodyards process more than 500.000 m^3 annually. They wish to reduce the number of woodyards and simultaneously increase their capacity.

D.W.K. Boulter (Canadian Forest Service) described the circumstances in Canada, which are comparable with the situation in the United States.

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[1]Paper presented at the conference COFE/IUFRO - 1984, Orono, Maine, USA, 12-14 August.

[2]R. H. Grammel, Institute for Forest Utilization and Work Science, University of Freiburg i. Br., Federal Republic of Germany.

He pointed out that in Eastern Canada the full-tree method with roadside processing makes up 15% of the wood production. Boulter mentioned that in Canada semi-mechanical and mechanical full-tree harvesting may be the best immediate alternative for achieving low costs. Further, he stresses advantages and disadvantages. In Canada, there are few publications that discuss how to optimize roundwood sorting; however, there is an increasing interest in central processing and sorting of treelength and full-tree timber.

For middle-European countries, Western France, Belgium, the Netherlands, Luxembourg, Northern Switzerland, and Northern Austria, the circumstances of West Germany can be considered typical. For softwood timber, 85% is harvested in treelength form and is sorted at the sawmills, while 15% must be used as loglength due to the poorer quality of the timber. Hardwoods are generally sorted in loglength form; there is only one sawmill which grades and sorts treelength hardwood (10-12m).

The West German paper industry obtains 19-20% of its softwood in treelength form. The trees are sometimes cut into loglength by a crane saw at roadside landings. The cellulose industry also uses treelength timber, especially those factories which use hardwood, particularly beech (fagus sylvatica).

In the tropical rain forests, trees are generally cut into loglengths in the forest; transport of the waste material such as branches would not be economically feasible.

There is only one exception - the JARI-Company in Brazil (Amazon). This company moves all the trees from a stand in treelength form and transports them to a huge woodyard. The land is then used for growing fast-growing plantation species. The advantage of this system is that 22% of the material is utilized for high value products, such as veneer, and the remaining 78% can be used as fuel for the pulp plant.

Results of our experiments show that central processing of hardwood in treelength form is profitable when the market is available. In addition, the technique for hardwoods is simpler than the technique used for conifers.

In reforested, fast-growing plantations of the tropics and subtropics, log-length systems are generally used. The applicability of central processing for these forests is being discussed intensively in Australia and New Zealand (C.M. Kerruish, L.O. Shultz, World Wood, April 1984).

Brazil, Chile and other South American Countries have noticed that the production of small-sized wood for cellulose and paper brings little profit; sorting systems must therefore be enlarged to obtain higher quality sawlogs.

PROBLEMS

Regions with comparable conditions often choose quite different solutions for handling their wood; this indicates that a question exists. In this context the reaction of the Joint Committee FAO/ECE/ILO is astonishing; on one hand a report was made, but on the other hand they consider work in this field to be finished. The program of work of FAO/ECE/ILO no longer includes an appropriate inquiry into wood processing techniques.

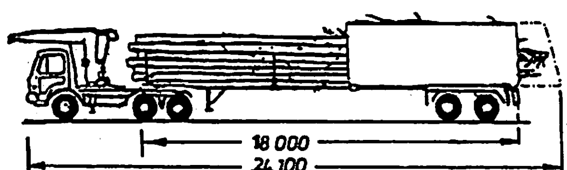
We, the IUFRO project group 3.01-07, are convinced that the problem must be discussed even more intensively than before. There are areas where intensive research is requested:

- economic field: mobile systems used in the forest or on skidding woods are more efficient and operate at lower costs. Woodyards must, therefore, compensate higher costs with a higher yield and an increase in wood quality.

  The central question is if these increases are possible. A large advantage for countries lacking inexpensive natural energy is that central processing of tree parts and whole trees produces bark, needles and limbs for fuel use.

- the problem of machinery replacement: In those countries which have largely introduced mobile systems, it must be determined if and when old machinery will be abandoned and new machinery subscripted.

- technical problems: Here the question of skidding technique must be examined. For example, how can skidding of full trees, tree-sections and treelengths be as efficient as log length systems? The same question arises for timber transport over public roads. Finnish experiments (O. Pennanen (1983), Truck Transport of Part-Trees (tree-sections) Metsateho Report No. 382) show that the transport of tree-part wood increased costs 67% for conifers and 25% for hardwoods. Our comparisons between transport only indicated a 10-12% increase in costs.



Fulltree-transport with semitrailer and steel box. The length of the trailor can be altered according to the size of the trees being carried.

Sorting is still a technical problem which is discussed intensively. There are attempts to increase output by use of multiple circular saws, automatic grading, computer optimization and automatic measuring of the outer and inner wood qualities. Progresses in this field can be expected.

- ecological problems: Increasing the amount of biomass taken from the forest will lead to a higher loss in soil organic nutrients. Today the loss of nutrients is much higher than when trees were debarked on the stamp. We must ask soil scientists for data showing the implications of increasing biomass removal. Whether organic materials or fertilizer can be added to the stand may influence the solution to this question.

SUMMARY

There seems to be no question that the central processing of trees on woodyards is a complete working system for the harvesting process. This basic concept is important to both the research scientist and the practical forester.

In order to decide for or against a system requires the consideration of related or even subjective factors such as safety, market flexibility, biological factors, etc. to financial parameters. The use of the entire tree will become increasingly important as raw materials become more scarce.

LITERATURE CITED

Abol, P.J. 1984. Lage und Methoden der primaren Bearbeitung des Rundholzes in den osteuropaischen Landern - regionaler Vortrag. TIM/EFC/WP.1/R.50/Add.3, 8. Marz 1984. Joint Committee FAO/ECE/ILO, Geneva (CH).

Akre, B. 1984. Location and methods of primary roundwood conversion - a subregional status report for the Nordic countries. TIM/EFC/WP.1/R.50/Add.1, 27. Februar 1984. Joint Committee FAO/ECE/ILO, Geneva (CHO.

Bjerkelund, B. 1983. Centralized tree processing, new opportunities for both forest and mill operations. Meeting of the Woodlands Section, Canadian Pulp and Paper Association, Toronto, Ontario, March 1983.

Boulter, D.W.K. 1984. Primary conversion centres in Canada: recent trends and developments - a subregional status report for North America. TIM/EFC/WP.1/R.50/Add.2, 2. Marz 1984. Joint Committee FAO/ECE/ILO, Geneva (CH).

Grammel, R.H. Centralized tree processing operations - with their emphasis and their effect on tree harvesting and wood delivery. XVII IUFRO World Congress-Japan 1981. Division 3, Subject Group 3.01-00.

Hakkila, P., P.O. Larsson, and C. Wibstad. 1984. Location and methods of primary roundwood conversion - a subregional status report for the Nordic countries. TIM/EFC/WP.1/R.50/Add.3, 8. Marz 1984. Joint Committee FAO/ECE/ILO/ Geneva (CH).

Hamilton, D.D. 1983. Fulltree processing comolex: a design for Canada. Canadian Forest Industries 103 (1983) Nr. 12, p. 14-19.

Kerruish, C.M. and L.O. Schultz. Centralized processing can increase log value. World Wood, April 1984.

Lohmann, H. and H. Lehnhausen. 1984. Systemanalyse eines Holzhofes durch Simulation des Materialflusses. Forstarchiv 54/6 S. 221-228.

Pennanen, O. 1983. Truck Transport pf Part-Trees. Metsateho Report Nr. 382.

LET'S CONCENTRATE ON THE SYSTEMS DEVELOPMENT PROBLEMS[1]

Magnus Larsson[2]

THE TRANSPORT ENVIRONMENT

The development and the operation of transportation systems is very strongly governed by the environment in which they are to perform their services. A large number of factors in the environment determine WHAT, WHERE and WHEN materials should be moved from the forest to the mills, heating plants, etc. These factors then constitute the framework for our transportation systems development work.

WHAT form the material will have during the secondary transport phase is in turn determined by the location of the different processing operations in relation to transportation. In other words, the design of the logging system will strongly influence the development of the transportation system. Figure 1 illustrates what happens when we, for example, centralize the delimbing operation thus changing from conventional shortwood logging to tree-section logging. New truck and trailer designs as well as routes and plans have to be developed.

These environmental factors naturally have various weights and they may also be influenced themselves by the transportation system as we are searching for the optimal solution from stump to mill.

For the purpose of this discussion the environment may be divided into primary and secondary factors. The primary factors have a direct influence on the transportation system - forestry practices, logging technique, forest industry structure, etc. The secondary factors constitute the conditions for the primary factors. Thus, they have an indirect effect on the transportation system. These factors are of a more general nature and vary considerably from one area (nation) to another - political system, economy, technical development stage, etc.

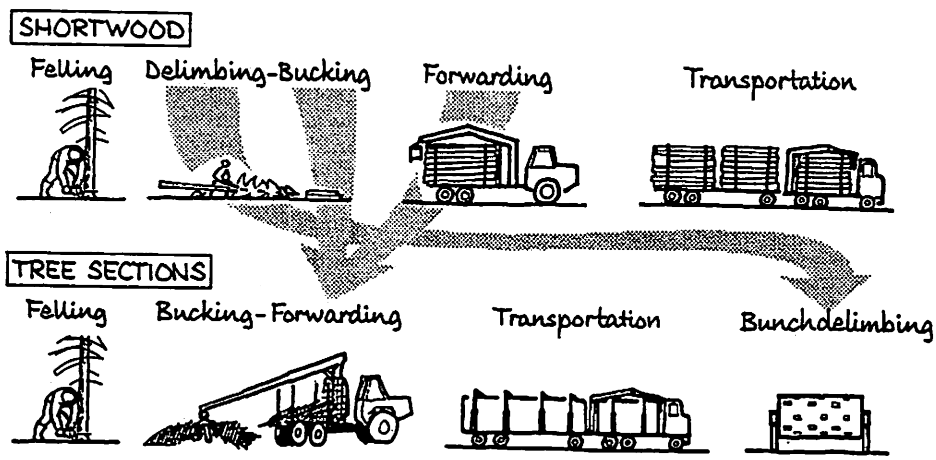


Figure 1. The logging system strongly influences the design of the transportation system.

WHERE and WHEN the transportation services should be provided are primarily a function of the structure, location and operating pattern of the producers (forest owners, loggers, etc.) as well as the consumers (mills and other users) of forest biomass.

THE DEVELOPMENT PROCESS

The process of developing a transportation system is schematically illustrated by Figure 2. The various production factors are combined to form a number of alternative systems. These systems are then analyzed and one or a combination of several systems are selected for operation. The criteria used for this selection is one of the major considerations in this process. The development is a continuous process even after the system has been set in operation. Feedback regarding the system operational performance may indicate needs for changes of the original systems design or even suggest another system.

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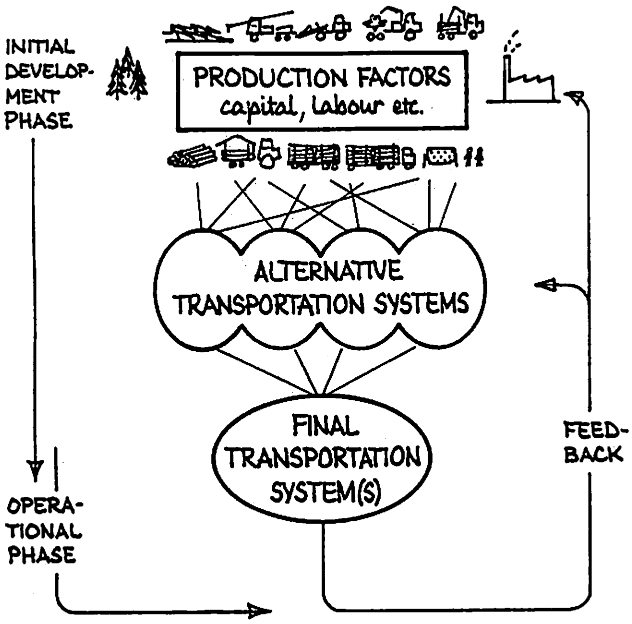
[1] Paper presented at the conference COFE/IUFRO - 1984. Orono, Maine, USA, 12-14 August.
[2] Dr. Magnus Larsson, Skogsarbeten, The Forest Operations Institute, Box 1184, S-163, 13 SPANGA, Sweden.

Figure 2. The systems development is a continuous process. Feedback regarding e.g. operational performance may indicate changes of the original systems design or even suggest another system.



THE TRANSPORTATION SYSTEM

The transportation system must meet the service requirements imposed upon it by the forest and the mill under a variety of conditions throughout the year. Therefore the technical parts (hardware) of the system must be controlled by an administrative part (software), see Figure 3.

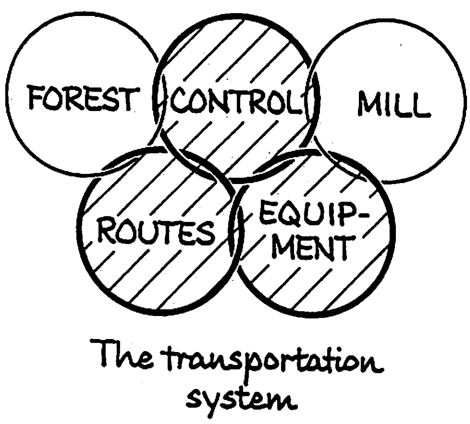
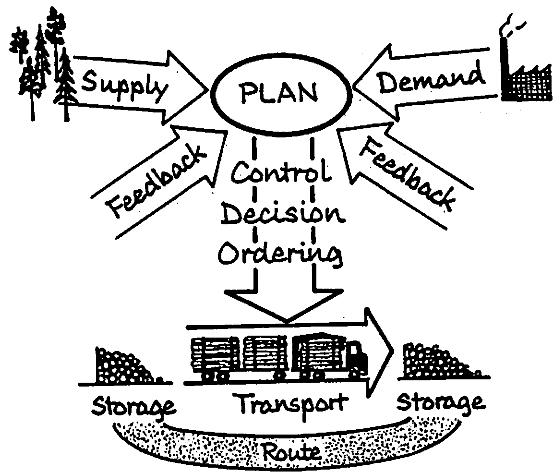


Figure 3. The technical parts of the transportation system must be controlled by an administrative part to meet the forest and mill requirements.

On the basis of demands from the industry and supply from the forest a plan for controlling the transportation activities (including storate) is made. The plan is continuously revised on the basis of feedback from the field as regards changing operating conditions as well as volumes logged, transported and stored, see Figure 4.

Figure 4. On the basis of demands from industry and supply from the forest a plan for controlling the transportation activities is made.



THE IUFRO WORK

Against this very general and simplified background I would like to focus your attention on the area where I personally believe the international cooperation within IUFRO would be beneficial to the largest number of participants.

The process and tools required to develop the transportation system should be of greatest general interest. Even if the secondary environmental factors are quite different the primary factors, the activities and thus the basic structure of the transportation problem are the same regardless of where it is being considered. Therefore the approaches used and the basic solutions both technical and administrative should be and are of common interest.

Descriptive information on very specific technical and administrative solutions is definitely of great interest. However, this should be limited to meetings which focus on problems within a certain geographic region or in areas with other conditions (secondary environmental factors) in common.

THIS SESSION

Largely in line with this philosophy the papers presented during this session deal with approaches to develop the technical part of the transportation systems in Finland and Japan. The development of an administrative tool for inventory control in New Zealand is also described.

THE INTERACTIONS OF HARVESTING
AND STAND ESTABLISHMENT OPERATIONS:
AN OVERVIEW AND PERSPECTIVE[1]

L. F. Riley[2]

A general discussion of the impacts of harvesting on stand establishment, stand establishment on harvesting and harvesting on harvesting is presented.

The interactions between harvesting and stand establishment are many and varied. They derive from biological and physical operational elements as well as environmental considerations. In Europe various of these relationships have been considered in some depth in many regions. In North America considerable attention has been paid in more recent years but since areas of man-made forest on this side of the Atlantic are relatively few in number and limited in area, experience is limited.

Regardless of the extent of past experience and the consideration which has been given to these interactions, harvesting methods and regeneration methods have changed dramatically since any presently mature, man-made stands were established. Thus, while in some parts of the world we may in fact be harvesting second or even third-growth forests, the effect of earlier stand establishment methods on today's harvesting practice must be extremely difficult to assess. And are we now in any better position to say what the effect of present-day stand establishment techniques will be on the harvests of the 21st century? But the effects of harvesting operations on stand establishment is ever present. There is seldom any doubt about that impact. The two usually occur very close together in time. The impact of the harvesting operation on future growth is another matter entirely. In most cases there is not yet enough evidence to be definitive but the potential for a strong relationship must be recognized.

To set the stage for the presentations to follow, I would like to consider some of these relationships in somewhat general terms and then ask my colleagues on the program to provide more specific detail on several aspects of the question, specifically those related to interactions between stand establishment and harvesting in deciduous and coniferous stands of northeastern North America, a look at some of these same interactions in the European experience and then, for a somewhat later stage in the life of the stand, the effect of thinning on harvesting and future stand growth. Colleagues from overseas may detect a somewhat North American flavour to my remarks. Indeed our friends to the south may detect a boreal flavour. But I shall try not to be unduly influenced by my place of birth and would hope that this overview treatment is broad enough that you will recognize the principles in play regardless of your own experience. And I will be the first to agree that the list will not be exhaustive.

Firstly, let us consider the most obvious -- the impact of harvesting on stand establishment. It's the one that the silviculturist complains about most often. Here the concern rests primarily with the silvicultural system, the harvesting method and the equipment used. While my statements will be general, it is recognized that the impacts or the effects, in any given area are influenced by, and vary with, site, forest type, species and species composition, terrain, condition of the present stand, availability of advance growth, markets, etc.

The approaches to harvesting vary widely, from clearcutting in patches or strips or over large areas, to various types of partial cutting including shelterwood cuttings, selection cuttings and high grading, the removal of a limited number of trees on a randomly spaced basis depending upon the commercial value of individual stems, to various seed tree methods. The form of management, for example even-aged versus all-aged or uneven-aged, bears heavily on the harvesting method to be used. Each of these suggest that certain reforestation options be considered or, perhaps more to the point, determine which options cannot or should not be used. For example, a large clearcut can be amenable to quite straightforward, large-scale, but high cost, plantings of various types of nursery stock, or to similarly large-scale but much lower initial cost broadcast seeding operations. The latter, however, has much greater stocking and density implications which may offset the immediate cost

[1] Paper presented at Council on Forest Engineering/International Union of Forestry Research Organizations Symposium - 1984. Fredericton, New Brunswick, Canada. 17-18 August.

[2] Lorne F. Riley, Research Manager, Forest Resources, Great Lakes Forest Research Centre, Department of the Environment, Sault Ste. Marie, Ontario, Canada.

savings. While dependent on the species to be established and the species on the site at time of harvest, large clearcuts generally demand that planting or direct seeding take place. Resident seed sources are usually inadequate and advance growth is largely destroyed. Efficiencies and cost savings in harvesting operations require high cost stand establishment alternatives of site preparation and artificial regeneration treatment. Lack of such treatment often results in regrowth by commercially inferior species. Large clearcuts also create harsh environments for new seedlings. It is doubtful that they are so severe as to preclude establishment success but more care is required in the development of microsite prescriptions for seeding or microsite selection when planting.

Other forms of clearcutting, e.g., in strips or in patches, are designed to give greater protection to the site and, of course, to provide sources of seed for the establishment of the next stand. These advantages are traded off against much higher harvesting costs. Again advance growth is largely destroyed or so severely damaged that surviving stems are often inferior throughout the next rotation.

Shelterwood cuttings, by their very nature, are designed to facilitate natural methods of stand establishment although the harvesting operation and the follow-up site preparation and cultural treatments may be very expensive. Favourable environments, particularly for the more shade tolerant species, are created and a high degree of success in restocking is the normal expectation. True selection cuttings have similar advantages and disadvantages but harvesting operations must be carefully planned and extraction routes rigorously adhered to to minimize damage to residual trees in this all-aged approach to forest management. The selection cutting known as high grading, particularly in its usual form as a series of harvestings of successively lower grade materials, does nothing but create silvicultural slums or "biomess" as it is sometimes called. This technique is commercially oriented and has few if any positive consequences for stand establishment.

Seed tree methods are essentially clearcuts with individual stems or groups of trees left to supply seed for the establishment of the next stand. They have many of the characteristics of larger clearcuts and a few of those of patch and strip clearcuts. One must hope, however, that money is available for the site preparation usually required when the seed supply develops, and that the trees are sufficiently wind-firm to remain until that time. One must hope also that when pressure is exerted to remove the seed trees, it can either be resisted or that damage to new stock is minimal during removal.

Within the various silvicultural systems one must consider also the actual felling and wood removal systems. What are the various effects of conventional shortwood operations where felling, limbing and bucking take place at the stump as opposed to tree length logging where all but the stump, the branches and the top are removed from the site? And what of full-tree logging where the tree from the stump up, including all branches and the top are removed? Or what of complete tree logging where even the stump is removed? To further complicate matters logging systems can transcend the boundaries of silvicultural systems. And each leaves its mark.

Conventional shortwood operations leave a large amount of debris on site which must be handled during stand establishment operations. Except where low cost labour is readily available in large numbers, heavy equipment is mandatory when ground disturbance prior to planting or seeding is required. Whether manual or machine planting is employed such debris, or slash, represents an obstacle that can dramatically increase the cost of the operation. On the other hand, finer cone bearing slash can be an effective seed source which, when properly handled in scarification operations, can effectively regenerate a site at relatively low cost. As with any direct or natural seeding treatment, however, there is little control of stand stocking and density without follow-up thinning or beating up operations. Tree length systems have much the same impact except that the debris left from the felling of trees to be removed has a much lower large wood content. Removal of cull material takes place at the landing, not in the bush. Scarification equipment can be lighter, and the scarification operation less costly, although fine slash in itself is a greater hindrance in planting, manual or mechanical, than heavy slash. Because of a complex of other factors which also come into play, the essential effect is little different than that of the shortwood operation. Large quantities of debris limit the number of potentially stockable locations but do have climate moderating effects for newly established seedlings.

In full-tree operations there can be a dramatic difference. Virtually all debris is removed thereby removing also many of the obstacles to stand establishment presented by the previously mentioned systems. The site is usually a forest managers dream from that point of view. There are, of course, detrimental effects as well which will be referred to later. A similar but little-used system, complete tree logging wherein stump and root material is used, has similar impacts although a new dimension is added. The holes or depressions left by the removal of root systems can play havoc with attempts to operate equipment on the site and present difficulties to planting crews in manual planting operations. Under these two systems, climate is not moderated by debris and the environment so created can be hostile to the developing seedling.

Harvesting equipment can have some of the most devastating effects for stand establishment.

In general, the less impact that a piece of harvesting equipment has, the better. This is not universally so, of course, but with present-day equipment beneficial effects of ground disturbance equipment are incidental, not planned, and therefore seldom controlled. It is well known that many of our "unexplained" reforestation failures are the result of hostile biological conditions created by man, not flukes of nature as we have so often been willing to believe. We cannot afford to accept substandard or inhospitable microsites in stand establishment operations. Therefore, methods which create conditions by happenstance are not acceptable, in and of themselves, as silvicultural treatments.

Much present-day equipment is designed for low ground pressure operation either through wide pad tracks, wheeled equipment with flex-tracks added, or some variation thereof. Other wood extraction techniques, e.g., cable yarding systems, do not require that machinery run through the bush at all, although damage may be extensive if large wood loads are dragged or trailed across the site. That North American phenomenon, the wheeled skidder, has perhaps the most devastating effect on site of any prime mover. Certainly this has been true of fragile wetlands where surface rootmats, once broken, can no longer support the machine and excessive churning of highly organic soils is frequent and common. The effect is to disrupt ground water flows and to cause "ponding up", a condition that saturates localized areas for prolonged periods of time suffocating tree root systems and preventing soil warming thereby inhibiting both tree establishment and growth. On heavier soils the high ground pressures applied by skidder tires, particularly when utilizing skidding trails where repeated runs are made, can cause severe soil compaction that precludes tree establishment or proper tree growth. Compaction is characteristic of other types of prime movers also but it seems to have been especially so with skidders. Because skidders are often operated in an unstructured manner, i.e., they tend to follow the route of least resistance on each trip out to the landing, damage of this type is often widespread throughout the area of operation. This created such a problem in some areas that many harvesting operations are now swinging to high flotation wide tires, a move that is doing much to overcome the problem. The danger is that such tires extend the range of sites on which skidders can effectively operate. We must be careful that operations do not extend into even more fragile sites in which there is no biological recovery from severe damage.

Manual felling operations are generally similar in effect to mechanical operations but there are some differences. For example, with the former, high stumps are commonplace in winter operations. High stumps are particualrly difficult for mechanical site preparation operations. Feller-delimbers tend to create piles of logging debris with some intermediate scattering rather than a more general distribution of slash over the operated site. In the former condition access through the planting chance may be less difficult but often significant area is effectively excluded for reforestation purposes because the piles cannot readily be redistributed in site preparation operations and are often left in situ. And, as a final example, although not an effect throughout the harvested area, delimbers and slashers located at landings and along roadsides in full-tree operations leave huge volumes of debris which generally remove significant areas from stand establishment treatment. These areas may never properly regenerate. Thus the productive forest base is reduced.

On a less obvious note, all forest managers can voice a note of thanks for the road systems that have been developed during the course of wood extraction operations. Certainly roads reduce the productive forest area and more care can be taken in the amount of land used for road rights-of-way. But it is those same roads that the forester uses as access routes for his stand establishment operations. It can be argued, in vain I'm convinced, that without the drive for harvesting of timber there would be no need for road systems for stand establishment purposes. But who really accepts that premise? Ask our European colleagues whose patterns of land tenure are so different from those of North America. And do we really believe that there is no need for forest husbandry for any other reason than commercial harvesting purposes? No, the infrastructures set up by logging operations are an essential part of our way of life and of definite benefit to stand establishment operations as well.

The effects of stand establishment on harvesting are, in some ways, more easily identified than those of harvesting on stand establishment, but they tend to be much more obscure when one attempts to evaluate extent. Indeed, given the period of time between establishment and removal, over much of the world's developed forestry areas, and the current and anticipated rapidity of technological change, it may be virtually impossible to quantify effects in any meaningful way.

The foremost effect, of course, is that it provides the raw material for the next harvest. Without stand establishment there would be no next harvest. The effect of man's intervention is the real issue. Do we, in fact, enhance the next harvest with our efforts or would we have a commercially viable crop without our input? We must believe that we do or we would not be devoting the resources we are, inadequate as they may be, to stand establishment. We can see from the denuded and barren tracts in various of the more arid areas of the world what can happen if we do not interfere. We can also seen the tragedy of no action in the "biomesses" of large tracts in temperate climates and in the boreal forests of our own Canadian northlands. There can be no question. Where man chooses to havest he has little option but to be the agent for the rehabilitation of the forest.

Obviously, through the species we plant or those whose establishment we foster in the various silvicultural systems, our goal is to provide products that we believe, now, will be of value 35, 50 or 100 years in the future. But how do we know what species will be suitable at those distant times? In truth, we don't. But we must have faith that basic biological values will remain constant even if the use to which we put the biological organism changes with time. And with that assumption we must proceed on the basis of the best knowledge available to us today. Species with fibre quality good for lumber today will still be good for lumber tomorrow. And species with fibre quality good for paper products today will still be good for paper products tomorrow, even if species now considered undesirable are added to the list of desirables and the list of products to be derived is beyond our present day comprehension.

The type and quality of product that will be produced is directly dependent upon our ability to provide "full" stocking and proper density. If fibre yield only is to be the end product, density can be much higher than if large single stems are deemed necessary for lumber production or for veneer production. Product type will probably be of greater concern to the harvester of the future than will stem size. Today, harvesting costs can decrease rapidly with increasing stem size, at least within a limited range. But harvesting methods and costs of the future will probably not be so sensitive to stem size.

One of the more perplexing questions posed by forest managers today relates to the appropriate density, or spacing, of a newly established stand for the product desired at harvest. Obviously spacing requirements change as the stand develops. The simple truth is we don't really know how many trees must be established on a given tract of land because we don't know what disasters will befall the stand nor do we know how well the stand will develop with respect to the intended product. Thus we must establish a stand with sufficient density to train the new stems properly and to foster their development toward that product. Within reason does it really matter how many stems there are at harvest as long as the product is what we need at the time? Thus we apply traditional spacings, only varying them at the outset to accommodate species and site peculiarities as we strive to produce the product anticipated. As the stand develops we fill in or thin out in an effort to maximize use of the land potential and minimize the length of the rotation. Let's get that next crop to harvest as quickly as possible. Time is money and the longer the crop takes to get to harvestable size the more costly it is.

Many of the effects of stand establishment operations on harvesting are indirect in that they prolong or shorten the rotation by changing the length of time for a tree to develop to a merchantable size for a given product type. Spacing, or density, is one such example. Site preparation operations can have such effects also. For example, in the case of prescribed burning, a severe burn may remove much of the nutrient reserve necessary for proper development of the new stand over the first few years of its life. On the other hand a moderate burn may, under proper conditions, actually enhance the available nutrient reserves, thereby assisting early stand development. A severe site preparation treatment may remove completely the fertile organic layers, or displace the organic materials so that their benefits are not readily available to the new stand. Impoverishment of the immediate microsite is a common occurrence in many mechanical site preparation operations. Again, however, a mixing of the mineral and organic layers can provide a reserve of nutrients that will promote tree development with benefits that will carry well into the juvenile stages of the life of the stand. Raised microsites, created by various means during scarification can make the difference between years of stunted growth and vigorous growth by improving soil drainage and aeration and allowing for greater warming of the soil and better development of root systems. Both manual and mechanical planting methods tend to contort root systems as opposed to stands arising from seed where root systems generally are natural in form. Whether this has any long-term impact on harvestability or rotation age is a moot point but there is no doubt that malformed root systems can have a major effect on tree stability and on whether or not sufficient trees in a stand reach harvest to make it economically viable. There are many such examples and these are just a few.

The severity of scarification can be of concern at time of harvest. Deep plowing and windrowing may present difficulties for terrain crossing harvesting units. At first thought this may seem unlikely but the effect of weathering will of course vary with the length of time from treatment to harvest. The shorter the rotation, and that's what we are striving for, short rotations, the greater the potential effect. We have examples of shallow plow lines still being quite evident in the stand 60 years after they were dug. Why should we suppose that ditches a meter or more deep, or windrows perhaps two meters or more high, will not be in evidence 50 years from now? We may be creating trafficability problems unknowingly because we blithely believe that all evidence of our efforts will have long since disappeared before future generations are required to return to the site. And for all we know, because of our lack of adequate effort today, those future harvesters may have to return to some of those sites much sooner than we expect.

So far I have been considering the effect of today's stand establishment operations on tomorrow's harvest. But consider for a moment the effect of today's stand establishment operations on yesterday's harvest.

In our efforts to improve upon stand establishment practice we have, in many areas, actually dictated the type of harvesting operation that would take place before we undertook the stand establishment treatment. I think you see where I'm coming from. It's not some esoteric concept, it's just an odd way of phrasing it and we've all had to consider it at one time or another. If we decide that the new stand can best be established by allowing seeding in from residual strips, we strip clearcut with all the attendant higher costs of that form of harvesting. If we operate under a shelterwood system, we have dictated that certain types of harvesting equipment must be used in order to minimize damage to the residual stand during the extraction process. If we decide that an area should be regenerated to a different species than the one on the site at harvest we may prescribe a clearcut followed by planting or seeding. Our preconceived notion of how best to reforest the site often indicates the form of harvest and wood extraction to be used.

Before closing I would like to consider, just briefly, one other interaction which generally has not been alluded to but which is very real and to which Professor Andersson has, in many ways, addressed his paper and that is the effect of harvesting on harvesting.

As we improve our harvesting efficiency, and as we become capable or desirous of removing more and more of the standing biomass from the logging chance, the more we run the risk of creating improverished sites through eventual depletion of the soil's nutrient bank. Now I am not, in general, a proponent of the theory of site impoverishment through biomass removal. But I think we must recognize that there are soil types and climatic conditions where organic material decomposition is so slow or nutrient release is so limited that any major, continuing removals of potential nutrient sources can have a devastating effect over a series of rotations. Under such conditions rotations become longer, tree quality can become poorer, and eventually no tree crop at all may be possible without massive interventions. Given the cost and extent of such investment, the return may not be sufficient to warrant it. Thus the effect of harvesting may be no harvesting. Also, it has been well established through the ages that denudation of a site without active efforts to replace the forest can result in massive erosions and desertification. We must guard against such catastrophes in our rush to provide wood fibre to the world's markets. In Canada particularly, our natural resources are what built the country. And the greatest of these resources is our forests. We must ensure that the forests remain, here and around the world, for all time. Foolish acts must not rob us of the heritage which we have in our various homelands.

In closing, I believe I have achieved the goal I set in preparing this overview, that is to show that there are strong interactions between the various stages of man's activities in the forest, to indicate that it is a system which man is superimposing upon a much more powerful system, the biological, and to re-emphasize for you, and myself, the fallacy of believing that harvesting and silviculture can be separated.

A SUMMARY OF CURRENT FOREST ENGINEERING RESEARCH

AND DEVELOPMENT IN THE UNITED STATES AND CANADA[1]

John W. Mann[2]

Abstract.--A survey of all known public sector forest engineering research and development insititutions in the US and Canada was conducted in the spring of 1984. Results of the survey show the current total research effort in this discipline is 116.6. scientist man years. Summaries of research topics by institution and a compilation of individual scientists with their area of specialization will be useful in helping researchers communicate more effectively among their colleagues.

One of the many benefits of attending the yearly meeting of the Council on Forest Engineering is the opportunity to learn who is doing what in research and development. Unfortunately, the full agenda only provides the opportunity to learn about a portion of the work that is ongoing in the forest engineering field. A comprehensive view of the work of every institution that is involved in this type research is, out of necessity, beyond the scope of the council's annual meeting. Since much of the information on current research must be developed through personal contacts, and we only have a short time together each year, I usually come away from the meeting knowing that I missed talking to someone.

As a possible remedy for this situation, this paper summarizes the results of a survey conducted over the past six months. Key personnel of 28 institutions in the US and Canada were contacted by mail and asked to complete a short questionnaire about their research. These 28 institutions were selected by evidence of their involvement in forest engineering research in the form of recent publications on related topics, participation in past meetings of the Council on Forest Engineering, and personal knowledge of faculty members at Oregon State University's Forest Engineering Department. The types of research units contacted fit into two general categories; colleges and universities, and government institutions. Individual companies in the private sector (forest products and heavy equipment manufacturers) were not included simply because of limited time available to conduct the survey and the possibility that information requested could be viewed as proprietary, thus precluding many companies' ability to respond. The organizations contacted are as follows:

UNIVERSITIES:

- Auburn University, Auburn, AL
- Univ. of British Columbia, Vancouver, BC
- University of California, Davis, CA
- University of Idaho, Moscow, ID
- Louisiana State University, Baton Rogue, LA
- Louisiana Technical Univ., Ruston, LA
- University of Maine, Orono, ME
- Mississippi State Univ., Starkville, MS
- Univ. of New Brunswick, Fredericton, NB
- North Carolina State Univ., Raleigh, NC
- Oregon State University, Corvallis, OR
- Purdue University, West Lafayette, IN
- State Univ. of New York, Syracuse, NY
- Virginia Polytechnic Institute and State University, Blacksburg, VA
- University of Washington, Seattle, WA

GOVERNMENT:

USDA Forest Service Experiment Stations:

- Intermountain Station:
  - Wood Resource Utilization Project - Missoula, MT
  - Engineering Technology for Forest Management - Bozeman, MT
- North Central Station:
  - Forest Engineering Research Work Unit - Houghton, MI
- Northeastern Station:
  - Hardwood Timber Harvesting - Morgantown, WV
- Pacific Northwest Station:
  - Forest Engineering Systems - Seattle, WA
- Southern Station:
  - Engineering Systems for Forest Management - Auburn, Al

USDA Forest Service Equipment Development Centers:

- Missoula Equipment Development Center - Missoula, MT
- San Dimas Equipment Development Center - San Dimas, CA

[1]Paper presented at the joint meeting of the International Union of Forest Research Organizations (Division 3) and the Council on Forest Engineering - 1984. Orono, Maine, USA, 12-14 Aug.

[2]John W. Mann is instructor of Forest Engineering and Harvesting Specialist with the Forestry Intensified Research (FIR) Program, Oregon State University, Medford, Oregon, USA.

Table 1.--Specific Areas of Forest Engineering Research and Development in the United States and Canada.

General Topic Area (Specific research topics in parenthesis)	Number of Institutions	Scientist Man Years
Timber Harvesting Operations (Plantation thinnings, steep terrain logging, wetland logging, small timber logging, whole tree chipping, production and cost analysis)	21	25.8
Road and Bridge Design and Construction (production rates, landslide relationships, erosion control, bridge design, transportation)	13	21.2
Forest Residue Recovery (wood as energy source, biomass harvesting)	8	15.4
Equipment Design and Analysis (Equipment mechanics, feller bunchers, mechanization of harvesting, equipment modification, improved components, balloon and hybrid aircraft design and testing)	11	12.1
Equipment Performance (Fuel consumption, maintenance, small woodlot logging)	8	5.9
Environmental Impacts of Forest Operations (Soil disturbance and compaction, watershed topics, damage to residual timber stand)	7	4.8
Site Preparation and Reforestation (Application of pesticides and herbicides, harvesting/site prep. trade-offs, cost analysis)	6	7.7
Computer Simulation of Forest Operations	4	4.6
Other topics: (Contractor monitoring, photogrammetry, harvest planning, timber mgmt., procurement, fire mgmt., basic research)	10	19.2
Total Scientist Man Years		116.6

Other US Government:
Helistat Development Project - Portland, OR
Tennessee Valley Authority - Norris, TN

Canadian Government:
Forest Engineering Research Institute of Canada - (FERIC)
Eastern Division - Pointe Claire, Quebec
Western Division - Vancouver, BC

Although much of the information pertaining to forest engineering research done in the United States is available through the USDA's Current Research Information System (C.R.I.S.), and governmental unit efforts are summarized periodically in various publications, there is no single source for this type data without making specific requests. Hopefully, this brief summary will provide a useful reference for research workers and users to see what institutions and scientists are working in what topic areas.

The questions asked in the survey and the responses received are summarized as follows:

1. Is this organization involved in Forest Engineering research and development?

26 Yes	0 No

(Two of the universities contacted did not respond to the request for information.)

2. What is the nature of this research? (Analytical, as in cost studies and operating techniques; or Developmental, as in equipment design.)

OVERALL RESPONSE:
- 9 Analytical only
- 4 Developmental only
- 14 Combination of both

Universities:
- 5 Analytical only
- 0 Developmental only
- 9 Combination of both

Government:
- 4 Analytical only
- 3 Developmental only
- 5 Combination of both

3. What are the specific areas of research in which you are involved? (summarized in Table 1).

4. What portion of your unit's research funding is provided by the following sources?

As would be expected, the funding for United States Government research institutions is 100% Federal Government. The Forest Engineering Research Institute of Canada is a cooperative effort funded 50% by the Canadian Government and 50% by private industry. A weighted average of funding sources for the 13 United States universities that responded is presented in Table 2.

Table 2.--Funding source weighted average for US university forest engineering research.

Funding Source	Average Overall Funding %	Range in Funding % for Single Institutions
McIntire-Stennis	21.8	5- 75
Hatch Act	1.9	10*
Other Federal Gov.	29.9	15- 75
State Government	20.0	5-100
Private Industry	24.8	9- 75
Associations	0	0
Foundations	0.8	10
Other (private contributors)	0.8	10

*Single number indicates only one university reporting this funding source or percentages were identical for institutions citing this funding source.

5. How do you decide where your forest engineering research efforts should be concentrated?

Decision Criteria	University	Government
Interaction with user groups	10	6
Advisory Committee	5	6
Funding source requirements	5	1
Faculty and staff interest	6	1
Problem analysis with user imput	1	
Administrative direction		2
Formal program reviews		2

6. What are the primary factors which limit your organization's ability to conduct research on forest engineering problems?

Limiting Factor	University	Government
Availability of trained personnel	9	7
Funding	11	10
User Interest	1	
Lack of organization to cross departmental lines	1	
Administrative Policies		1

7. Please list your forest engineering faculty (or research staff) by name and area of specialization.

A list of researchers by institution and area of specialization is contained in Table 3. Table 4 summarizes total forest engineering researchers by country and employment.

According to the latest summary of public sector research effort in agriculture compiled by the USDA in 1982 (Inventory of Agricultural Research, Volume I) the 94 scientist man years spent on forest engineering research in the United States shown by this survey amounts to approximately 6 percent of all forestry research.

Hopefully, this brief look at who is doing what in forest engineering research will help us develop our personal contacts at this and other meetings more efficiently and will form the basis for other summaries of this type in the future.

Table 3.--Forest engineering faculty (or research staff) by name and area of specialization.

Institution & Location	Researcher	Area of Training or Specialization
Universities:		
University of British Columbia (Vancouver, BC)	G. G. Young	Micro-Computer Application
	J. D. Nelson	(New faculty - no research yet)
University of California-Davis (Davis, CA)	John Miles	Equipment Design
	Bruce Hartsough	Operations Research
	Jim Burk	Production Analysis
	Jim Mehlschau	Hardware Design
University of Idaho (Moscow, ID)	Leonard R. Johnson	Industrial Engineering
	Harry Lee	Forest Roads/Hydrology
Louisiana State University (Baton Rouge, LA)	Ben D. Jackson	Economics Analysis
	Michael W. Jenkins	Computer Modeling
Louisiana Tech. University (Ruston, LA)	Clyde G. Vidrine	Power & Mechanics
University of Maine (Orono, ME)	Thomas Corcoran	Systems Engineering
	Ben Hoffman	Timber Harvesting
	Marshall Ashley	Remote Sensing
	Warren Hedstrom	Roads & Structures
	Tom Brann	Computer Graphics
	Norm Smith	Energy Engineering
	Tom Christensen	Equipment Development
	Louis Morin	Surveying
	Hayden Soule	Soil & Water Engineering
	Ed Huff	Power Engineering
Mississippi State University (Starkville, MS)	W. F. Watson	Production & Operations Analysis
	R. K. Matthes	Agr. Engr./Instrumentation
	I. W. Savelle	Production Analysis
North Carolina State University (Raleigh, NC)	Awatif E. Hassan	Mechanized Silviculture
	Earl Deal	Harvesting (Extension)
Oregon State University (Corvallis, OR)	George Brown	Hydrology
	Paul Adams	Soils
	Bob Beschta	Hydrology
	Hank Froehlich	Hydrology
	John Garland	Harvesting (Extension)
	Loren Kellog	Small Wood Harvesting
	John W. Mann	Harvesting/Silviculture
	Dave McNabb	Soils
	Don Miles	Soils
	John O'Leary	Harvesting/Transportation
	Eldon Olsen	Harvesting (Ind. Engr.)
	Marv Pyles	Geotechnical Engineering
	John Sessions	Harvesting/Transportation
	Brian Tuor	Harvesting/Surveying
Purdue University (West Lafayette, IN)	Harry G. Gibson	Equipment Design
	Gary W. Krutz	Equipment Design
	Philip E. Pope	Biomass Harvesting
Syracuse University (Syracuse, NY)	Robert H. Brock	Photogrammetry Engineering
	Duggin	Remote Sensing
	Hassett	Water Resources
	Hennigan	Water Resources
	Hopkins	Surveying
	Lee	Soil Mechanics

Syracuse University (con't)	McClimans	Hydrology
	Palmer	Engineering Economics
	Tully	Engineering Hydrology
V.P.I. & S.U. (Blacksburg, VA)	Tom A. Walbridge	System Simulation
	W. B. Stuart	System Simulation
	R. M. Shaffer	Harvesting (Extension)
University of Washington (Seattle, WA)	Francis E. Greulich	Operations Research
	Peter Schiess	Soil Mechanics
	Jens E. Jorgensen	Mechanical Engineering
<u>Government Agencies</u>:		
Intermountain Station (Bozeman and Missoula, MT)	E. R. Burroughs	Hydrology
	M. J. Gonsior	Harvesting Systems
	R. W. Prellwitz	Geotechnical Engineer
	C. Hammond	Slope Stability
	P. Heumier	Hydrology
North Central Station (Houghton, MI)	James A. Mattson	Research Engineer
	John A. Sturos	Research Engineer
	Nels S. Christopherson	Research Engineer
	Michael A. Thompson	Research Engineer
	Sharon A. Winsauer	Mathematician
	Michael A. Wehr	Mechanical Engineer
	Edsel D. Matson	Mechanical Engineer
	Bengt-Olof Danielsson	Visiting Research Forester
Northeastern Station (Morgantown, WV)	Penn Peters	Aerospace Engineer
	Cleve Biller	Mechanical Engineer
	John Baumgres	Forester
	Chris LeDoux	Industrial Engineer
	Ross Phillips	Mechanical Engineer
Pacific NW Station (Seattle, WA)	Charles N. Mann	Mechanical Engineer
	Ronald L. Copstead	Mechanical Engineer
	Edwin S. Miyata	Industrial Engineer
	Roger H. Twito	Civil Engineer
Southern Station (Auburn AL)	Donald L. Sirois	Biomass Harvesting
	Bryce J. Stokes	Thinning Systems
Missoula Equip. Dev. Center (Missoula, MT)	Art Jukkala	Fire Management
	Bob Ekblad	Pest Control
	Ben Lowman	Site Preparation
	Tony Jasumback	Cable Yarding
	Eli Milo	Cone & Seed Collecting
San Dimas Equip. Dev. Center (San Dimas, CA)	Raymond Merala	Fire Management
	John McDermott	Fire Management
	Mike Smith	Fire Management
	Ed Gililland	Forest Roads
	Jim Bassel	Math./Physics
	Leonard Della-Moretta	Math./Physics
	Phil Fisher	Forest Resources
	Dan McKenzie	Forest Resources
	Ken Dykeman	Forest Resources
	John Krischuk	Forest Resources
Helistat Development Project (Portland, OR)	Virgil Binkley	Logging Systems
	D. Nearhood	Logging Systems
Tennessee Valley Authority (Norris, TN)	Dennis Curtin	Harvesting
	Paul Barnett	Biomass Recovery

FERIC - Eastern Division (Pointe Claire, Quebec)	G. P. Chinn	Engineering
	P. G. Mellgren	Equipment Design
	J.M. Cote	Equipment Design
	G. S. Franklin	Forest Engineer
	R. Levesque	Operations Research
	E. Heidersdorf	Systems Evaluation
	M. Folkema	Processing
	M. St.Amour	Processing
	D. Ljubic	Transportation
	J. Courteau	Transportation
	D. Massicotte	Transportation
	W. Novak	Equipment Maintenance
	M. Ryans	Forest Resources
	E. Stjernberg	Forest Resources
	E. Vajda	Forest Resources
FERIC - Western Division (Vancouver, BC)	Vern Wellburn	Engineering
	Bob Breadon	Engineering
	Don Moulson	Mechanized Felling
	Michael Nagy	Road Construction
	Alex Sinclair	Log Handling
	Don Smith	Transportation
	Daniel Guimier	Mechanized Felling
	Ingrid Hedin	Silviculture
	Ray Krag	Rock Work
	Tony Saunder	Cable Yarding
	Tony Wong	Forestry
	Kristi Knox	Geography

Table 4.--Scientists working in Forest Engineering research in United States and Canada.

Country and Organization Type	Scientist Numbers
United States:	
Federal Government	43
Universities	56
Sub-Total	99
Canada:	
Federal Government (FERIC)	27
Universities	2
Sub-Total	29
Total	128

LOGGING SYSTEMS RESEARCH IN CALIFORNIA[1]

John A. Miles[2]

Abstract.--This paper gives a brief summary of various logging systems research being conducted in California. Included are discussions on helicopter logging, all terrain vehicle development, brush handling systems, cable logging damage research, skyline payload analysis techniques, and cable yarder power flow analysis and rigging equipment development.

INTRODUCTION

Ladies and gentlemen, it is an honor and a pleasure to be able to speak to you this afternoon. In order to discuss logging research systems in California. I must first tell you a bit about California itself. As well as being the most populous state it contains both the highest and lowest geographical points within the continental United States. With respect to forestry, California ranks second only to Oregon in the production of lumber and is a major producer of softwood plywood. This year we expect to produce 3.5 billion board feet of lumber.

Within California lies some of the most diverse forest to be found anywhere in the world. Forty million acres (2/5 of the state) bear forest cover. Included are the oldest known trees (white bark pine), the largest (Sierra big trees), and the tallest (coast redwood). California forests are of vital importance as a source of wood products, as protective cover for major watersheds, as habitat for characteristic fish and important wildlife, and as playground for millions of people.

About 16 million acres of commercial forest provide raw material for the production of lumber, plywood, pulp, and various other forest products. The industry is concentrated in a great horsehoe which extends northward along the coast from Santa Cruz County to the Oregon border, eastward to Modac county, and then south along the Sierra Nevada to Tulare County. Forest products industry provides annual employment for about 100,000 people and generates annual payrolls of 1.25 billion dollars. Slightly more than half of the commercial forest is publicly owned, most of it in the National Forest. Only 1/6 of the commercial forest is owned by the forest products industry. The remainder is held by farm and other owners, much of it in small holdings of 20 to 80 acres.

Before 1940, lumbering was generally on a modest scale and, where cut over land was protected from fire, naturally regenerated second growth forest usually developed. Following World War II, forest products output in the states expanded rapidly, reaching a peak in the late 1950's. During the last two decades saw log production has been slightly declining, as limitations on the available supply of merchantable timber become more binding. Most of California's commercial forest has been harvested at least once, and significant areas have been subjected to two or even three harvest cuts. Virgin forests are largely restricted to the national forest system. As logging activity expanded the impacts of road construction and careless logging practices had significant adverse affects on soil erosion and water quality. A significant percentage of cut over land was not adequately stocked with conifers, so the annual wood growth was less than half of its actual potential. These conditions reflected the fact that, until about 1960, the timber industry was still an economic frontier. Wood supplies were relatively large and values were still low. There was little or no economic incentive for forest conservation. Although this economic environment has been transformed, many reminders of this recently closed forest frontier still remains.

Californians make heavier and more diversified demands on their forests than any other people in the industrialized world. They demand a high level of per capita consumption of wood, a larger amount of forest spaced recreation, a higher standard of water quality control, and more attention to the environmental ammenity than do forest dependent communities elsewhere.

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[1]Paper presented at the conference COFE/IUFRO-1984. Orono, Maine, USA, 12-14 August.

[2]John Miles is Associate Professor of forest engineering, University of California, Davis, California, USA.

RESEARCH AREAS

The first research area I would like to share with you is that related to aerial logging (Hartsough 1983). Large helicopter systems are able to move logs from the reasonably undisturbed forest to a landing very rapidly; however, the cost of operation is $3,000 to $4,000 per hour, which usually makes helicopter operations the most expensive of our logging systems. Figure 1 shows a portion of the analy-

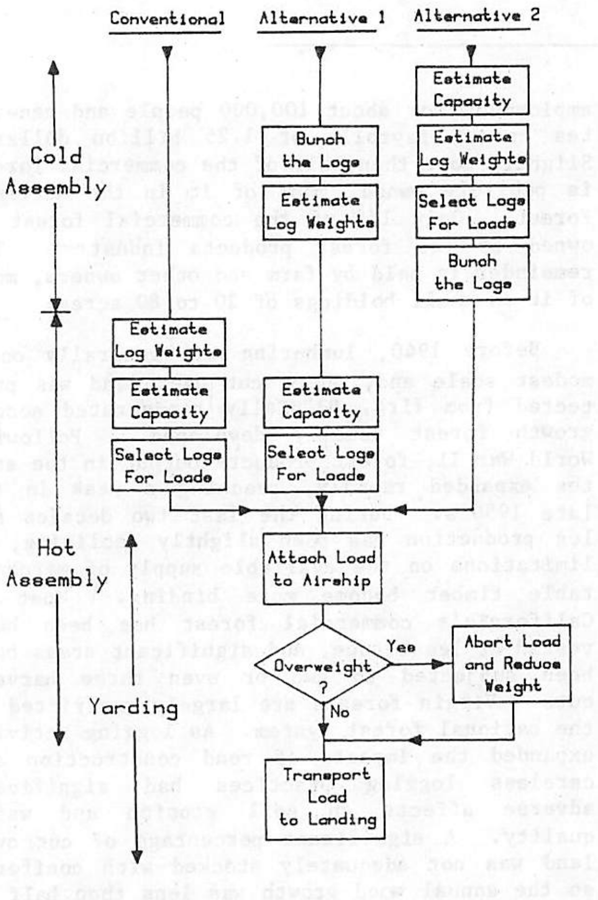

Figure 1. Examples of log-to-landing sequences.

sis we have used in order to improve the efficiency of aerial systems. The system efficiency is heavily dependent on achieving optimum loads. Figure 2 shows the effect of abort and loading on the total cost of transporting fiber.

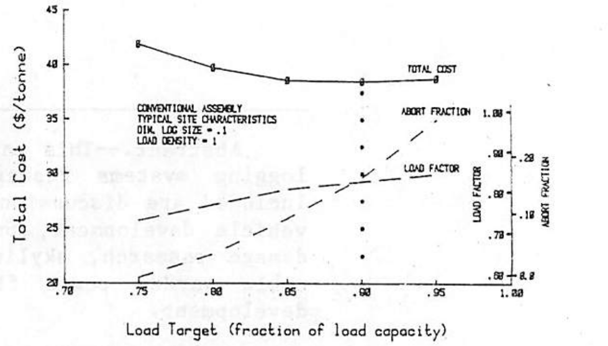

Figure 2. Selecting load target to achieve minimum total cost.

California also has about 20 million acres of shrub-covered foothills. Our research efforts on these lands has concentrated on reducing fire danger and recovering biomass for energy. One of our first projects was to develop a low-cost all-terrain vehicle for operations both in the forest and on the range lands (Miles 1980, Miles 1983). This vehicle (fig. 3) uses a unique suspension system which allows us to operate on very difficult terrain. Several

Figure 3. U.C. Davis forestry power module.

versions of this vehicle have been designed and constructed, with the objective of making low cost mobile power available for forestry operations. One application is shown in figure 4, where thinnings are being cut, piled and bundled in the woods.

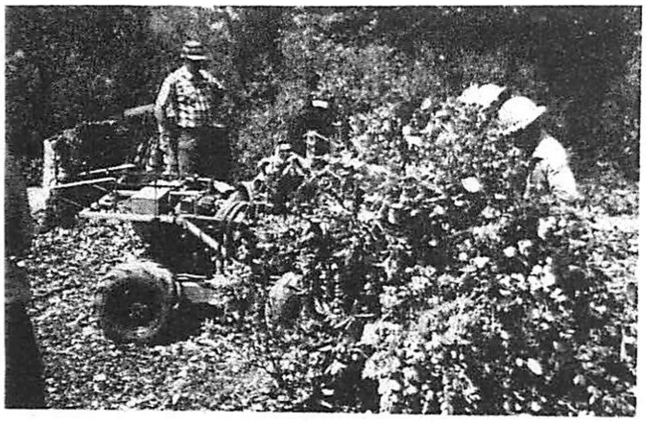

Figure 4. Forestry power module used in brush bundling operation.

The bundling is accomplished by laying two wide nylon straps on the ground, piling the thinning material on top of them, and then raising the straps over the top of the pile and pulling them tight. Steel banding is then added to permanently restrain the pile. These 1,500 to 2,000 pound piles are then allowed to air dry in the sun. One operator is presently developing a removal system which uses the 27 horsepower track-type tractor shown in figure 5. The piles are winched laterally onto the trailer and then carried to a road.

Figure 5. Small 27 hp track-type tractor with trailer used to transport brush bundles.

We have also used the cotton-module builder system to organize forest residue (Miles 1983). Our modules were 32 feet long, 8 feet high, and 8 feet wide. Pieces as large as 32 feet long and 10 inches in diameter were incorporated within the module. As yet, no attempt has been made to remove these module from the forest.

Another project has investigated the reasons for extensive damage to residual stands during cable thinning (Miles 1984). We have attempted to reduce the number of parameters which need to be addressed in carefully controlled studies. Detailed analysis of removal mechanics indicate some operations, such as down-hill yarding, are very difficult to achieve with current systems.

We are also introducing new modeling techniques (Hartsough 1984). The technique of using virtual work to describe skyline mechanics is much more flexible than the current method of developing equations from statics. We have also learned that models based only on wire-rope size are frequently poor estimators of yarder load capability. We are in the process of developing models which also include the characteristics of the engine, the clutches, brakes, torque converter, gear drive and drum sets in order to improve these models.

For a number of years we have been working to reduce the weight of running skyline tail blocks without reducing the diameter (Miles 1980), (Miles 1983). We are presently testing an 18 inch nylon block which weighs about 35 lbs. less than its steel equivalent. It has now been used operationally for about 9 months and we are in the process of building six more blocks to be tested on other operational yarders.

Finally, I need to mention our work on forest soil compaction. Californians have been very concerned about the affects of compaction on the residual forest and we have been actively involved in the search for scientific data to address these concerns. (Miles 1978), (Baker 1981).

Once again, it has been a pleasure to be with you today, and I hope to see all of you at Lake Tahoe for our COFE meeting next summer.

LITERATURE CITED

Baker, Keith J. 1981. The Effects of Tractive Logging Equipment on Forest Soil Density. Thesis, University of California, Davis, Agricultural Engineering Dept., Davis, CA.

Hartsough, Bruce R., J.A. Miles and M.B. Lambert. 1983. Modeling Load Assembly Methods for Heli-State Logging. Transactions of the ASAE, Vol. 26 No. 2 pp. 357. American Society of Agricultural Engineers, St. Joseph, Michigan.

Hartsough, Bruce R., and J.A. Miles. 1983. Modeling Cable Logging Systems with Virtual Work Relationships. ASAE Paper No. 83-1613. American Society of Agricultural Engineers, St. Joseph, Michigan.

Miles, John A. 1983. A New Method to Recover Logging Residues for Energy. U.C. Appropriate Technology, Univ. of California, Berkeley, Berkeley, CA.

Miles, John A. and J.E. Burk. 1984. Relationships Between Cable Logging Practices and Damage to the Residual Forest. ASAE Paper No. 84-107. American Society of Agricultural Engineers, St. Joseph, Michigan.

Miles, John A. and J.W. Rumsey. 1980. Development of a Self-Propelled Forestry Power Pack. Transactions of the ASAE, Vol. 23, No. 4, pp 1002. American Society of Agricultural Engineers, St. Joseph, Michigan.

Miles, John A. and J. Mehlschau. 1983. An Improved Power Module for Forest Operations. ASAE Paper No. 83-1623. American Society of Agricultural Engineers, St. Joseph, Michigan.

Miles, John A. 1980. Development of a New Block for Cable Logging. Transactions of the ASAE, Vol. 23 No. 6 pp. 1540. American Society of Agricultural Engineers, St. Joseph, Michigan.

Miles, J.A. 1983. Improving the Performance of Nylon Sheaves for Use in Cable Logging. USDA, Forest Service, Pacific Northwest Forest and Range Experiment Station, No. PNW-81-153. Portland, Oregon.

Miles, John A. 1978. Soil Compaction Produced by Logging and Residue Treatment. Transactions of the ASAE, Vol. 21, No. 1, pp. 60. American Society of Agricultural Engineers, St. Joseph, Michigan.

DECISION MAKING IN FOREST RESEARCH OPERATION WITH HELP OF POLAR-CO-ORDINATES CHART[1]

Adolf Schlaghamersky[2]

One of the simplest methods to determine the optimal solution of various harvesting technologies is the polar-co-ordinate method. Alternative technological systems should be compared to each other, not on basis of simple economical or technical units, but on the basis of areas between co-ordinates.

INTRODUCTION

In planning timber harvest operations, especially hauling processes, proper scheduling and decision making concerning various types of man-machine-systems can lead to significant cost savings. Thus, it could be possible to reduce the production costs and attain a good position in the competition on the timber market. If the amount of money available for the production of certain goods were unlimited, there would be no need for operations research. This is, however, not the case today. The salary of forest workers is rising rapidly. It is this kind of salary explosion which makes our work difficult. Thus, the forest manager must search for the optimal combination of various production systems. The efficiency of the production processes is characterized by maximum profits, and maximum production of goods with minimal expenditure of human labor. To reach this goal is the main task of the decision maker. For this purpose he uses operational research techniques such as linear programming, "spider network" analysis, simulation, etc. There are many methods to find the best solution. One of the simplest methods to determine the optimal combination of various technologies is the polar-co-ordinate method. It uses the "spider network" approach in order to characterize various production systems. It can be used in decision making concerning various timber harvesting operations.

DESCRIPTION

This method was first mentioned and described by Prof. Pampel (1978), University of Dresden, GDR. It combines graphical charts and simple mathematical techniques to arrive at the optimal solution. Alternative production systems should be compared to each other, not on basis of economical units such as $, DM or technical units as m^3, m, feet or by output m^3/h etc., but on the basis of the triangular areas between two-co-ordinates. In such a manner it is possible to add up machine output (m^3) and its fuel consuption (liter). The indicators of operations are given on the co-ordinates in a certain scale. The smallest area between co-ordinates with various values of units of operation variants determines the optimal solution. The result depends on the units used.

In addition, the total sum of areas can be expressed as an algebraic equation such as

[1]Paper presented at the conference COFE/IUFRO-1984. ORONO, Maine, USA, 12-14 August. Adolf Schlaghamersky

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$$F = \sum_{1}^{n} A, \quad A = 1/2\ a \cdot b \cdot \sin\gamma$$

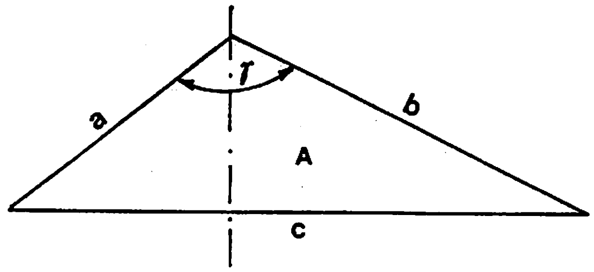


Figure 1.

Example:

System description: Mechanical debarking of short wood - 2 m long pieces.

Input value of indicators:

Co-ordinate No. 1: - output/productive machine hour (ph) = 4,0 m^3/ph

" No. 2: - costs per fuel and lubricant/ph = 6,0 DM/ph

" No. 3: - number of workers = 3 workers

In order to simplify the calculation the angles γ_1, γ_2, γ_3 should be identical (see Fig. 2).

Angle between two co-ordinates

$\gamma = 360/3 = 120^o$

$\gamma_1, \gamma_2, \gamma_3 = 120^o$, $\sin 120^o = 0{,}866$.

Coefficient for the calculation of the triangular area = 0,5 (see $A = 1/2\ a \cdot b \cdot \sin\gamma$).

$$\begin{aligned} \text{Area: } A_1 &= 0{,}866*0{,}5*4*6 = 10{,}39\ cm^2 \\ A_2 &= 0{,}866*0{,}5*6*3 = 7{,}79\ cm^2 \\ A_3 &= 0{,}866*0{,}5*3*4 = 5{,}20\ cm^2 \\ F &= 23{,}38\ cm^2 \end{aligned}$$

Scale section - 1 cm on the co-ordinate equals 1 unit of the indicator.

The total area of above mentioned system covers 23,38 cm^2.

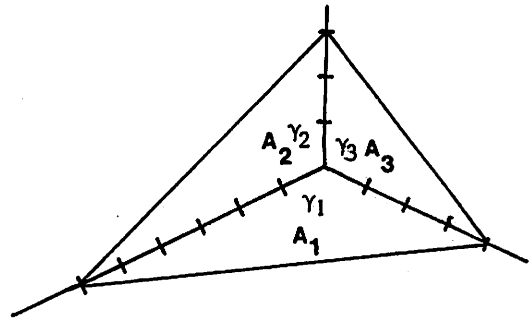


Figure 2.

It should be noted that with some scale indicators it is necessary for the correct calculation to put the scale in reverse in the system of co-ordinates. The starting point of the scale is in such cases not in the center of the chart, but <u>outside of it</u> (Fig. 3).

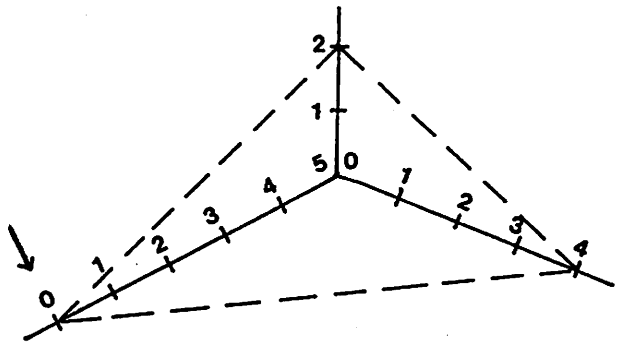


Figure 3.

The scaling of the indicator values on the co-ordinates, especially the fixing of the starting point of the scale is the most important task in using this technique.

If two or more processing systems are compared to each other and if one of the available indicators does not have greater value than zero in the co-ordinate center, then the two areas between three co-ordinates are disregarded for the calculation. To avoid this disadvantage, the value 1 will be added to each indicator's scale, in such casses. Fig. 4.

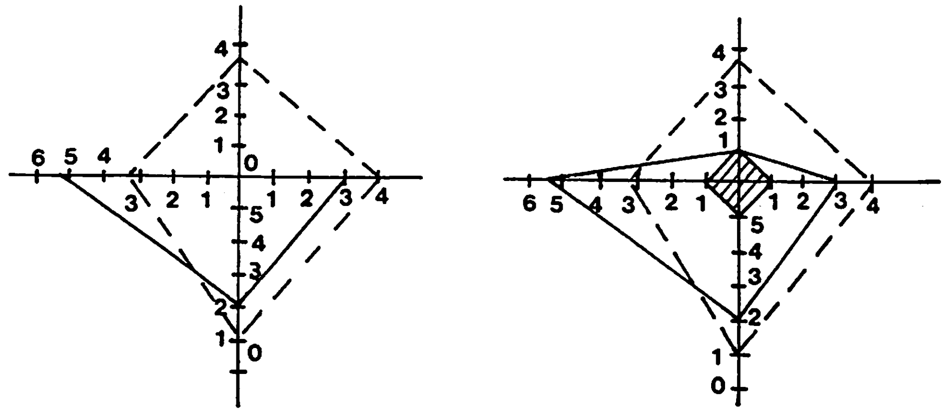


Figure 4.

Scaling of values

The evaluation of the indicator values in co-ordinate charts is possible by using different scaling of values.

Let us calculate a simple example to show how important the section- scaling on the co-ordinates ist.

All date is based on information from KWF, Institute for testing of forest machinery, Groß Umstadt, West Germany.

Consider spruce thinning operation (Fig. 5):

The thinning operation can be carried out by four main activities:

1. felling of trees,
2. prehauling with winch,
3. processing of trees,
4. hauling of an assortment to the landing place.

In addition, this example illustrates how the problem of determining the best machine system can be solved in a realistic decision making setting. The question is how to find the best processing machine for the thinning operation, if we can use three different types of processing machines, e.g.:

- Processor Rottne 750/Snoken 780
- Processor Brunett 578 F
- Processor Cetto MM 400

The felling, prehauling and hauling of ready assortment with forwarder is the same for each of these systems. The prehauling was carried out with the assistance of a small radio-controlled winch Nordfor.

The input data are summed up in table 1.

Thinning operation chart
(short wood conversion)

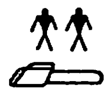
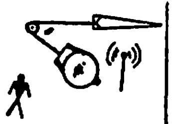
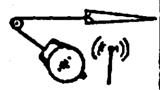
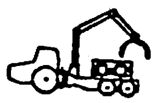
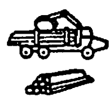
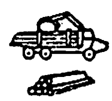
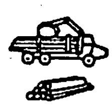
work elements \ working place	stand	skidding way	forest road landing
prelimbing cutting			
prehauling with cable			
processing			
hauling			
unloading			

Figure 5.

Wood conversion by help of agricultural tractor

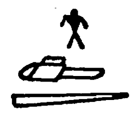
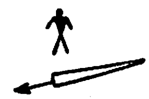
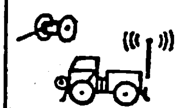
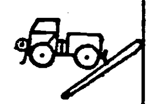
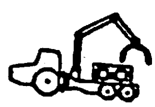
work element \ working place	stand	skidding way	forest road
felling			
delimbing			
prehauling			
hauling			
unloading			

Figure 6.

 radio controlled winch - NORDFOR

 processing machine

 forwarder

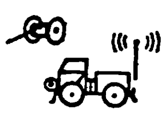
 tractor with radio controlled winch

Table 1.

Nr.	Indicators	Processing machine types Cetto MM 400	Brunett 578	Rottne 750
1	Production costs DM/m^3	87,-	85,-	89,-
2	Salaries in % (personal)	48,-	51,-	47,-
3	Capital investment cost in 10.000,- DM	39,5	34,3	39,5
4	Processor costs DM/ph	145,-	131,-	151,-
5	Production time min./m^3 (D.B.H 12 cm)	68	68	68
	min./m^3 (D.B.H 17 cm)+	43	40	37

+partly adapted for this example

Calculation of the area between the co-ordinates:

4 indicators, $\gamma = 360/4 = 90^o$, $\sin 90^o = 1{,}0$.

Area: A 1 - Cetto MM 400 :

$= 1/2\ (87*48 + 48*39{,}5 + 39{,}5*145 + 145*87) = 24.414\ mm^2$

A 2 = Brunett 578 : = 21.712 mm^2

A 3 = Rottne 750 : = 25.443 mm^2

<u>Sequence:</u>

1. Brunett 578 ... 21.712 mm^2
2. Cetto MM 400 ... 24.414 mm^2
3. Rottne 750 ... 25.443 mm^2

In this calculation only 4 indicators were used. If 5 indicators are used, the sequence will be different:

Indicators No. 1, 2, 3, 4, 5 (D.B.H 17 cm): Fig. 6

1. Brunett 578 ... 15.818 mm^2
2. Rottne 750 ... 17.591 mm^2
3. Cetto MM 400 ... 18.035 mm^2

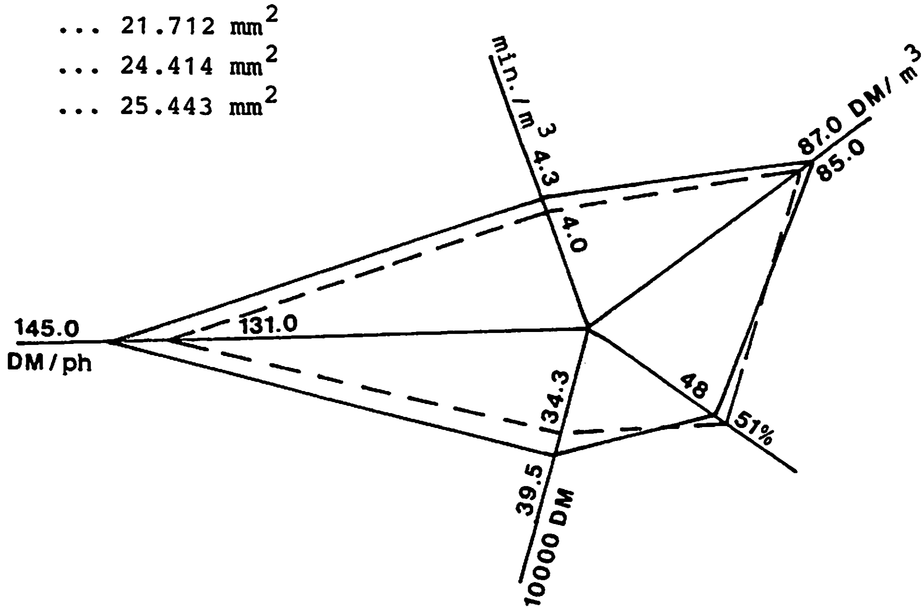


Figure 6.

The indicator scale and the number of indicators are very important criteria, especially if the areas in question are approximately the same, as in the example above. According to the literature there is a special "sensibility test" to check and determine the right scale for the co-ordinates. In any cases, from this view of point, the determination of the scale is subjective, depending on the experience of the decision maker.

Another important point is the use of the same unit sections on the scale for all alternatives which are tested.

Another Model-Calculation

Since the polar-co-ordinates method is based on simple mathematical formulas the use of a small pocket computer is possible.

Consider the following model of beech wood conversion operation (thinning and processing with machine).

Data basis:

Average tree volume: 0,165 m^3, D.B.H: 17 cm

Assume the following alternatives in the conversion procedure:

Alternative:

V 1: Standard wood procedure EST, assortment - pulpwood 1 m long

V 2: Standard wood procedure EST, assortment - pulpwood tree-length

V 3: Small winch hauling with the cutting - assortment - pulpwood tree-length

V 4: Standard wood procedure (felling, delimbing, measuring, pre- and hauling with an agricult. tractor), assortment - pulpwood tree-length, Fig. 7.

Let us take the following maximal indicator values:

1. machine- man output ... 3,0 m^3/ph
2. net profit ... 30,0 DM/m^3
3. hauling costs ... 30,0 DM/m^3
4. standard wood conversion costs (felling, limbing, bucking, measuring and hauling) ... 60,0 DM/m^3

The alternative V 4 not direct hauling costs have to be specified, because they are already included in the total sum of operation costs. These costs are zero such that it is necessary to add 1,0 to all indicators values (table 3).

Multiplication constant factor:

4 indicators = 4 co-ordinates

$k = 360^o/4 = 90^o$, $\sin\gamma = 1,0$

Table 2. -- Data for comparison of different conversion procedures of beech wood

Alternatives		V 1	V 2	V 3	V 4
conversion costs	DM/m^3	53,37	23,69	33,63	47,39
hauling costs	DM/m^3	18,57	25,00	15,00	-
net profit	DM/m^3	16,57	23,76	23,82	25,06
output	DM/ph	0,80	1,70	1,81	1,16

The data base (matrix) must be adapted for the caculation (table 3).

Table 3. -- Conversion of data for the polar-co-ordinates method

Alternatives		V 1	V 2	V 3	V 4
conversion costs (+1)	DM/m^3	54,37	24,69	34,63	48,39
hauling costs (+1)	DM/m^3	19,57	26,00	16,00	1,00
net profit (max.value - value from tab. 2)	DM/m^3	14,44	7,24	7,18	5,94
output (max. value - value from tab. 2)	m^3/ph	2,20	1,30	1,19	1,84

Calculation of the areas:

V 1: 0,5*54,37*19,57 = 532,01 cm^2
0,5*19,57*14,44 = 141,30 cm^2
0,5*14,44* 2,20 = 15,88 cm^2
0,5* 2,20*54,37 = 59,81 cm^2

749,00 cm^2

V 2: 0,5*24,69*26,00 = 320,97 cm^2
0,5*26,00* 7,24 = 94,12 cm^2
0,5* 7,24* 1,30 = 4,71 cm^2
0,5* 1,30*24,69 = 16,05 cm^2

435,85 cm^2

V 3: = 359,36 cm^2

V 4: = 77,15 cm^2

From these results following hierarchy can be obtained:

1. V 4 - Conversion by help of agricultural tractor ... 77,15 cm^2
2. V 3 - Standard procedure with small winch ... 359,36 cm^2
3. V 2 - Standard procedure -tree length ... 435,85 cm^2
4. V 1 - Standard procedure -pulpwood 1 m long ... 749,00 cm^2

If the zero value is not located at the center of the chart, the difference between the max. value (which was chosen) and the value from tab. 3 must be fixed on this co-ordinate e.g.

net profit = 30 DM/m^3 (max. value) - 14,44 DM/m^3 (data table 3) = 15,56 DM/m^3 (this is the value which should be put on the ordinate) Figure 8.

CONCLUSION AND DISCUSSION

With the help of the polar-co-ordinate method it is possible to compare different technological alternatives in primary wood conversion techniques and to determine the best one. This method makes it feasible to add up non-uniform technical and economical units in the form of certain triangular areas. In this way it is easy to find the optimal alternative in the system. The simple calculations require only the use of a small pocket or table computer.

The only disadvantage to be mentioned relates to the difficulty of scaling or weighing the INPUT values on the ordinates. There are some points (e.g. fixing down the max. value) where it is impossible to eliminate completely subjective influence. Great accuracy is required for the scaling (Rippelbeck, J., Schlaghamersky, A. (1983)).

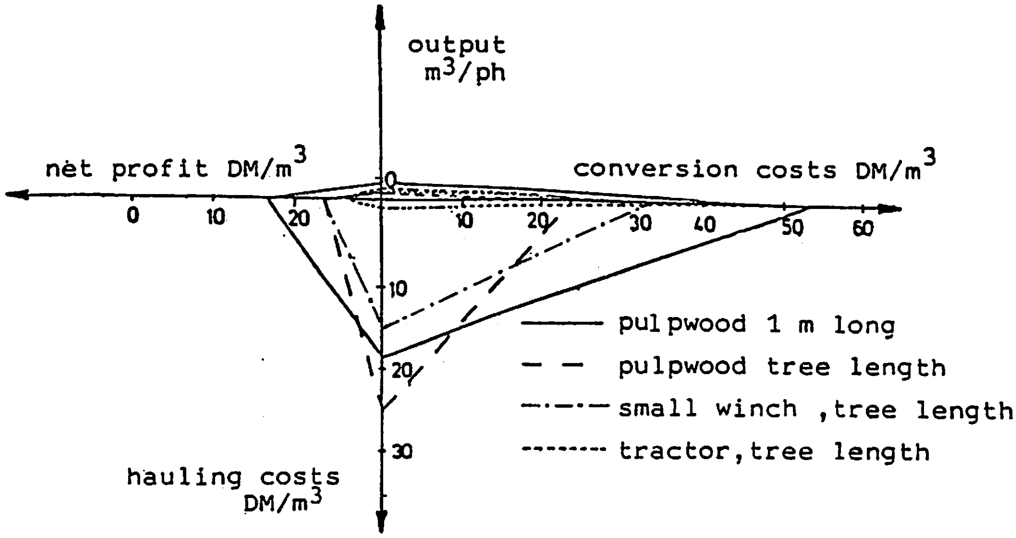


Figure 8.

LITERATURE CITED

KWF-Tagungsführer 1981. Bestandesbegründung im Mittelgebirge. Kuratorium für Waldarbeit und Forsttechnik, Groß Umstadt, Fed. Rep. of Germany.

Pampel, W. 1978. Grundlagen der Forsttechnik und Forsttechnologie, Berlin, German Democratic Republic.

Rippelbeck, J., Schlaghamersky, A. 1983. Polarkoordinatendiagramm als Entscheidungshilfe für den praktischen Forstbetrieb. Holz-Zentralblatt, Stuttgart, Nr. 117, S. 1624-1625, Fed. Rep. of Germany.

PREDICTING PRODUCTIVITY USING INTERACTIVE MODELS FOR SKIDDERS[1]

Eldon D. Olsen[2]

Interactive computer models of skidding productivity give important operating information to users. Vehicle velocity and tire load estimates are two examples. Alternative skidding situations such as top-first skidding verses butt-first skidding can be compared. Rules of thumb on load and vehicle weight distribution can be shown to be inaccurate.

INTRODUCTION

Principles of mobility may be applied to operations with a rubber-tired skidder by computer simulation of the movement of logs (Olsen and Gibbons, 1983). Interactions of the vehicle and log with terrain can give reasonable estimates of productivity and insight into the effects of such variables as skidding distance, vehicle horsepower, ground slope, turn weight, soil strength, and load geometry. The model will aid logging managers in choosing a skidder, planning skid trails, or gathering an optimal turn of logs. The program is written in BASIC and runs on a desk top (personal) computer.

APPLICATION AREAS

The model was originally intended as a production estimating tool. It now appears that the model's ability to compare operating methods is in itself valuable. The model indicates when limiting conditions have been encountered. The user can then make changes using interactive feedback. The following list represents some of the options that can be investigated.

- Compare the production of horsepower classes
- Determine optimal turn weights for a range of slopes
- Show impact of skid trial layout on production
- Establish a breakeven distance on uphill and downhill skidding
- Compare production under various soil strengths (operating season effect)
- Compare production with wide tires versus standard tires
- Show the effect of tire ballast
- Compare the production of butt-first versus top-first tree length pieces
- Compare whole tree skidding versus delimbed tree skidding
- Compare the production of arch skidding versus nonarch skidding
- Compare the production of grapple versus choker machines
- Test vehicle design modifications (arch location).

INPUT

The input consists of information about the load, vehicle, terrain, and operating practices.

Load

Weight (pounds)
Average stem length (ft)
Whole tree or limbed (y/n)
Butt-first or top-first (y/n)
Suspended or ground lead (y/n)

Vehicle

Center of gravity location (inches)
Arch lead point location (inches)
Length of wheel base (inches)
Tire dimensions (inches)
Skidder weight (pounds)
Flywheel horsepower (horsepower)

Terrain/Skid Trail

Percent slope (%)
Distance (ft)
Soil strength (cone index pounds per square inch)

Operating

Non-travel time (minutes)
Tire ballast (pounds)
Speed limits (miles per hour)
Tire load limits (pounds)
Utilization (%)
Cost per hour ($)

Most of this information can be obtained by an analyst from manufacturer's literature and from a knowledge of field conditions. Since the program only calculates travel times, the user must supply an accurate estimate of the nontravel time (winching, hooking, decking). Default operating conditions are automatically used if the user chooses not to enter values. Up to 20 different sets of terrain conditions can be entered for a single skid trail.

If the center of gravity location is unknown, the program requests the weight distribution between the axles on an unloaded skidder on level ground. An approximate center of gravity location is then calculated and displayed. In cases when a cone penetrometer is not available to measure the soil strength, a trial cone index can be input. A calculated tire sinkage is displayed back to the user. If this tire sinkage does not agree with the sinkage observed in the field, another trial

[1]Paper presented at the conference COFE/IUFRO - 1984. Orono, Maine, USA, 12-14 August.

[2]Eldon D. Olsen is an associate professor of Forest Engineering at the College of Forestry, Oregon State University, Corvallis, Oregon, USA.

cone index can be entered. In the output section that follows, a 50 p.s.i. index was entered and a sinkage of 2.60 inches was reported back. If less sinkage was actually observed, then a higher cone index could be entered.

The remaining information needed for the analysis are either constants or calculated values. These can easily be changed by altering the line statements in the program. The present program contains conversion constants based on the English units shown. Conversion to metric units could easily be accomplished by changing the appropriate constants.

The program contains prompts which request each input. If an incorrect response is entered, the program gives an audible beep and asks for the information again. The vehicle must successfully travel through all the conditions entered both loaded and unloaded. If a limiting condition is encountered, the user is informed. The program then asks for the following sequence of alternatives:

New load weight?
New skid trail?
New vehicle and/or tires?
Change operating practices?

If new values are entered the entire calculation procedure is repeated, otherwise the program says "goodbye".

OUTPUT

An example of the output will be given for a 110 horsepower vehicle pulling a 10,000 lb load of butt-first, limbed, 32' logs. An adverse slope of 20% grade with a soil strength of 50 p.s.i is being attempted. First, load information is reported.

Log weight on ground = 3,113 lbs.
Log resistance = 6,009 lbs.
Winch line tension = 9,406 lbs.

The analyst can check if these appear reasonable. In this case, approximately 31% of the log weight is being supported by the ground. The log resistance is the combined drag and grade resistance. The winch-line tension is within the safe working strength of wire rope as well as within the winch's pulling capability. Next, the vehicle information is reported.

Load front axle = 6,371 lbs.
Load rear axle = 19,833 lbs.
Loaded rear tire sinkage = 2.60 inches
Unloaded rear tire sinkage = 0.41 inches
Rear tire ground pressure = 21.03 p.s.i.
Front tire ground pressure = 6.75 p.s.i.

In this example, the rear tires are carrying most of the weight. The program alerts the user if this weight is above the recommended tire load. If the front axle weight is less than 100 lbs, the user is informed that instability is likely. This means steering ability is lost and the front wheels may leave the ground. The program also warns the user if tire sinkage exceeds 20 inches. If these limiting conditions are encountered the program halts and asks for new conditions. The program also reports the approximate ground pressure based on an assumed tire contact area (foot print) for the size tires used. The ground pressure indicates the potential compaction effect of the situation. Next the slip and velocity are reported.

Slip loaded = 38% or 0.38
Slip unloaded = 10% or 0.10
Velocity loaded = 1.63 mph
Velocity unloaded = 12.00 mph

This output indicates that a successful skid was accomplished. Note that considerable slip (a range of 0.10 to 0.30 is typical) was encountered which indicates that this adverse skid on weak soil is difficult. The program begins at 0.10 slip and then increase at 0.01 increments until it can achieve a wheel pull capable of overcoming the log, grade, and rolling resistance. If it can't achieve this pull one of three causes is reported.

Load exceeds capacity of vehicle
Adverse slope can't be climbed unloaded
Lowest gear has insufficient power.

In the example above, the velocity loaded is near the lowest gear's capability. The unloaded velocity is the default limit of 12 mph which was entered by the user to indicate how fast the driver was willing to go downhill unloaded.

The final output is the production rate.

Total round trip time = 9.11 minutes with no delays
Productivity = 5.49 Mbf per hour with delays
$/Mbf = 10.93

The round trip time is the cumulative travel time for all conditions plus the user entered non-travel time. The productivity is calculated from the turn time, turn weight, and user supplied delay information (utilization percent). Finally, the skidding cost per unit volume is calculated. Volume measurements other than Mbf can be used by modifying one line statement.

OTHER APPROACHES

Because of the complex interaction between the load, vehicle, and terrain, this interactive approach to predicting travel velocity has a major theoretical advantage over empirically derived regression equations. Hassler, et al. (1983) reported a similar interactive skidder model called SKIDLOG. SKIDLOG does a more accurate job of modeling the load weight and distribution. It also uses a more accurate velocity calculation method. On the other hand, it uses a less rigorous approach to calculate the axle loadings. The slip value is user-specified.

In this sample output, rules of thumb are inadequate. The percentage of load weight transfered to the vehicle is affected by the load geometry, load center of gravity, and slope. The commonly used 50% to 67% rule of thumb is on the low side in most cases.

A rule of thumb that the weight distribution on a moderately loaded skidder's axles is equal is only true on a steep downhill skid. In other situations, the back wheels usually have the majority of the weight. Assuming that the weight is equally distributed results in a pull prediction that is 10% too high on steep uphill skids. It also badly underestimates the ground pressure and tire load.

One of the major strengths of this model is its ability to more accurately calculate the vehicle/soil interaction. The interactive model's production results are comparable to those reported by equipment manufacturers.

LITERATURE CITED

Hassler, C.C., S.A. Sinclair, and D.J. Ferguson. 1983. SKIDLOG...An interactive skidding model. J. Forestry 81/9:610-613.

Olsen, E.D. and D.J. Gibbons. 1983. Predicting Skidder Productivity: A Mobility Model. For. Res. Lab., Oregon State Univ., Corvallis. Research Bulletin 43. 19 p.

ANALYZING AND SIMULATING TIMBERYARDS

H. Lohmann, H. Lehnhausen

Abstract. -- Some principal aspects concerning the transfer of a complex technical system into a computer program for simulation studies are discust. The possibility to run simulation studies on the technical behavior of the material flow in a timber yard has been proved. Example outputs of several simulation runs are presented.

INTRODUCTION

During the last years different kinds of timber yards have been installed in the FRG, especially by prived forestry companies. Under our production and marketing conditions there are different oeconomic reasons for centralised round wood preparation. The main effect on the profit of the wood producers will be reached by sorting small wood (diameter smaller then 20cm) and offering very differentiated sortiments of round wood logs. Studies show that timberyards can get better results then decentralised working prozessors (at least with small wood).

But as one is faced with quite a big amount of fixed costs with such a centralised solution one has to be careful in planning such an investment, not only concerning the market conditions but also the choose of the technical installations.

The aim of our study was to try an evaluation of different technical constellations by implementing simulation runs on a digital computer. The first step was to find out if it is possible to "copy" reliably an existing timber yard into a computer program in limited time.

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1) Paper presented at the conference COFE/IUFRO - 1984. Orono, Maine, USA, 12-14 August.

2) Dr. Hubertus Lehnhausen is employed by the forest service of the county of Hessen, West Germany. Dr. Helmut Lohmann is working in the Institut of Soil Science and Forest Nutrition of the University of Göttingen, West Germany.

STRATEGIES FOR SIMULATING COMPLEX SYSTEMS

A scheme of the installation we tried to copy is given in Fig.1. To simulate the technical behavior of such a system you have to orientate in two directions:

1. on the system itself, its principles, variables, entities etc.
2. on the software instruments you want to use for programming and simulation.

In both cases you always have to look for complementaries to find out the best modelling strategy and the formal formulation in the computer program.

To begin with the simulation instrument: there are different philosophies for realising the modelling and programming of the system.

a) From the begin you can concentrate on the variables of interest and their behavior in time. In that case you might look for strategies like FORESTER used in his continues modelling approach (realised in DYNAMO, CSMP etc.).

b) Such a variable orientated opproach can also be realised as FISHMAN described it by his discret controlled systems (variables change at times of events).

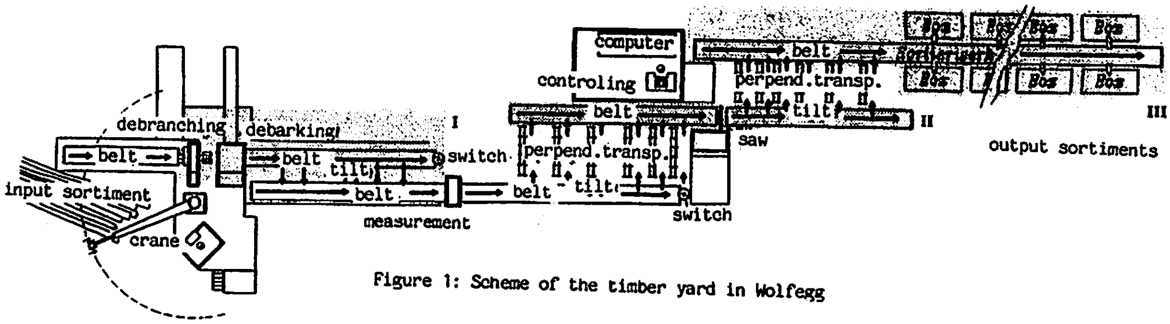

Figure 1: Scheme of the timber yard in Wolfegg

c) But you can also try to concentrate on the technical behavior of the system. And for that you should apply so called process or activity orientated modelling strategies and software intruments.

For our study we used SLAM which encloses support of all 3 mentioned philosophies and even can mix them. We applied the process orientated part of SLAM but we also used some event controlling facilities in our program.

The timber yard system consists of well defined subsystems (or "processes") which are only linked together by a sequential arrangement. Through the subsytems stems are running as entities. For a reliable programming of such a complex system it will be necessary first to realise the different basic processes step by step. After that you link the basic parts to more complex subsystems etc. At the end you will reach the whole system in a hierarchical manner. At each step of the hierarchy you have to test your model und programming before you can go a step further on.

PRINCIPLES IN BEHAVIOR AND CONTROL OF THE TIMBER YARD SYSTEM

We already mentioned that a timber yard is a sequentially organised system of activities. The sequential working is supported by queues in front of each activity. But the principles of our system can be classified and explaned by further characteristics of the timber yard:

1. Single trees (ENTITIES) are put into the system by a crane.

2. A network of conveyor belts and perpendicular transporters serve to conduct the entities from one process (queue and activity) to the next one.

3. Some times you need special RESOURCES (in our case: a crane,tilts, special belts).

4. There are installations in the system which have (beneath their main function) an effect on the flow of the entities through the system. They are working as GATEs (in our case the saw is working in such a way because all flow in front of it has to stop until the predecessor tree is sawed into logs). These gates can be opened and closed and equivalently start and stop the flow of the entities.

5. Most of the model knots are characterised by waiting queues where the entities are waiting for the next activity.

6. At some places in the system very special things (called EVENTS) are happen. In our case such an event has to be realised at the saw where a long tree is cut into different smaller logs. At that time from one entity several new entities (the log pieces) are created and have to be inserted into the system.

7. One of the main characteristics of the system timber yard is given by the fact that the time behavior of the system is primaryly controlled by the entities and their attributes and their behavior in the material flow. For instance in case of a long tree which is

cut in many pieces the trees behind it have to wait for a longer time in front of the saw then in case of a small tree. You may imagine how complicated this controlling can be.

From these few principles you can deduct the basic terms of our real system for which you have to look for analogons in your software instruments and which you have to model and programm: You need a sequential network structure of queues (knots) and activities, entities which are running through that network, resources and gates as well as event-control equipment. But you also need variables of interest for output as well as parameter variables for the calibration of the basic system parts. A software system like SLAM offers such terms. So SLAM or a similar simulation language becomes a necessary instrument for a reliable and time-saving computer simulation of the system.

THE SIMULATION MODEL AND ITS INPUT AND OUTPUT

The formulated and programmed model of the timber yard is graphically shown in Fig.2 (for symbols see PRITSKER and PEDGEN (1979)). SLAM offers a kind of modular system for different kinds of knots, activities, events etc. and also a control system for the material flow and the system's behavior in time between start and end. The parameters for speed of activities and the sawing algorithms as well as the attributes of single trees (length, diameter) are the input of the modell and the simulation runs. You can of course change this input as you like.

The output of the calculations will be the variables of interest you are gathering during the simulation run. In our case these variables can be of different type:

1. Measurements concerning the whole system
   - whole time the system needs for treating fixed number of trees
   - capacity of the system in meters per hour
   - occupation of special aggregates (saw, crane)
2. Measurements concerning entities
   - mean time between two logs
   - mean time of log in a special subsystem
   - mean time of log in the whole system
3. Measurements concerning input and output sortiments

We will not explain the model specifications and their realisation in detail because for that you need more information about the philosophy and the structure of SLAM or another program package. But in view of our hierarchical concept of modelling and programming we should mention that the system was first realised in 3 subsystems. (In Fig.1 and Fig.2 they are marked by shading and numbered by I, II and III.)

RESULTS AND EXPERIENCES

As input for our simulation runs we used data from input sortiments of the timber yard in Wolfegg. So we were able to make some kind of validation of our model. Concerning the analysis of the timber yard system we made a lot of simulation runs. One of our results was that disturbances in the material flow (trees get stuck, reoptimisation for sawing in case of diseased logs et.) have considerable influence on the capacity of the system. For some aggregates it should therefore be helpfull if they possess some kind of independent buffer (waiting queue) so that subsystems are not be fixed dependent on the results and on disturbances of other aggregates.

At the end we will give an example of results of the simulation. In Table 1. you find results of 8 different sized simulation runs (200 input stems). Variable 1 to 6 are input parameters which were changed successively (only one at one time). Variables 7 to 20 show output quantities. Such quantitativ findings however are not the only results of a simulation study. Another important effect you will get with simulation is that you will learn a lot about the principles of your analysed system already by the "translation process" of copying a real system in a very formal manner into a computer program which has to be concipated quite flexible for parameter change and variable control from the begin.

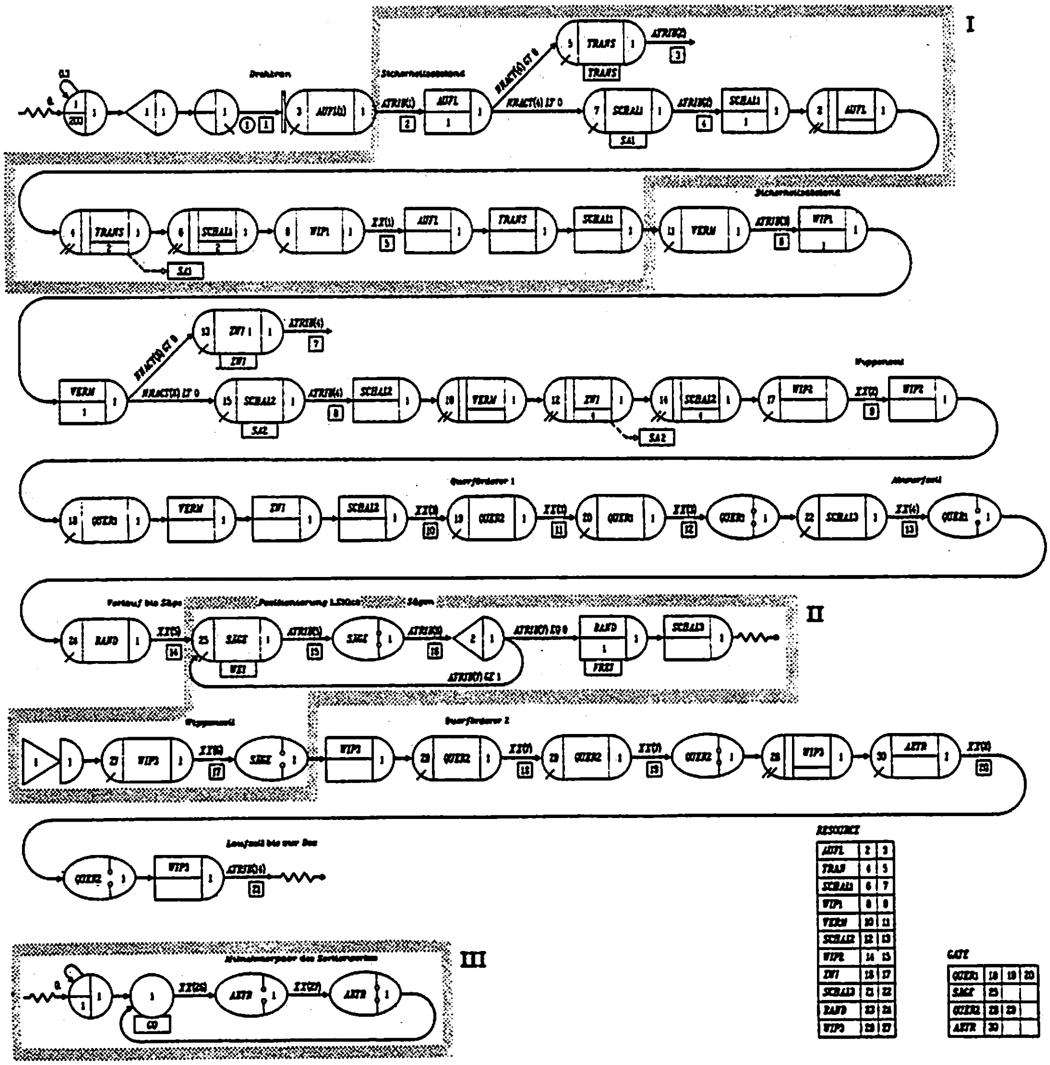

Figure 2: symbolic draft of the simulation program

Acknowledgements:

The data about input sortiments and the material about installations we get from Forstdirektor Dr. DUFFNER (Wolfegg, Baden Württemberg). His support was important for the sucsess of this study. The simulation was done on a UNIVAC 1100/83 of the Gesellschaft für wiss. Datenverarbeitung Göttingen (GWDG).

LITERATURE CITED

Duffner, W. (1983). Zentrale Holzaufarbeitung als Betriebssystem. Forstwiss. Centralblatt 102(3): 206-213.

Fishman, G.S. (1978). Principles of Discrete Event Simulation. New York, Brisbane.

Forester, J.W. (1961). Principal of Systems. Cambridge.

Grammel, R. (1981). Holzvermarktung über forstliche Holzhöfe. Bonn, CAM.

Lehnhausen, H. (1982). Computerunterstützte zeitliche und räumliche Simulation forstlicher Systeme an den Beispielen Holzrückeprozeß und Materialfluß auf einem Holzhof. Dissertation. Universität Göttingen.

Lohmann, H., and Lehnhausen, H. (1983). Systemanalyse eines Holzhofes durch Simulation des Materialflusses. Forstarchiv 54(6): 221-228.

Pritsker, A.A.B., and Pegden, C. (1979). Introduction to Simulation and SLAM. New York, Chichester.

Table 1: 8 simulation runs, without sorting system
input sortiment of 200 stems, mean length 13.5 meter
no reoptimisation

simulation run number		1	2	3	4	5	6	7	8
variable label	*SLAM–Variable*								
parameter variables (speed)									
1 belt debranching/debark.	xx(20)	42.	84.	42.					84.
2 tilt to measurem.belt	xx(1)	0.083		0.041	0.083				0.041
3 belt at measurement	xx(21)	48.			92.	48.			92.
4 tilt to 1.perpend.transp.	xx(2)	0.083				0.041	0.083		0.041
5 1. perpendic.transp.	xx(3)	0.083					0.041	0.083	0.041
6 tilt to saw belt	xx(4)	0.057						0.025	0.025
variables of interest	units								
7 time for whole input	min	126.9	126.8	119.6	113.2	119.0	126.8	126.9	106.9
8 capacity	lfm/st	1238.7	1238.1	1310.4	1386.7	1317.4	1237.9	1235.2	1467.9
9 mean length of input stems	m	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
10 mean number of logs/stem	–	3.9	4.0	3.9	4.0	4.0	3.9	4.0	4.0
11 mean time betw. 2 stems	min	.62	.62	.59	.55	.58	.62	.62	.52
12 variation of 11	–	.11	.07	.10	.15	.10	.10	.11	.13
13 mean time input→ saw	min	.62	.62	.59	.56	.59	.62	.63	.53
14 variation of 13	–	.08	.08	.09	.12	.09	.08	.07	.13
15 mean time input→ 1.perp.trp.	min	1.67	1.68	1.62	1.40	1.58	1.68	1.68	1.38
16 mean time on 1.perpend.transp.	min	0.40	0.41	0.42	0.80	0.38	0.28	0.36	0.78
17 mean time in saw	min	0.50	0.51	0.50	0.50	0.51	0.50	0.51	0.50
18 mean time in system	min	2.57	2.59	2.54	2.71	2.47	2.47	2.54	2.66
20 saw unused	%	21.0	20.4	16.0	11.7	14.8	20.6	20.3	5.7
21 sawed logs smaller 2 meter	–	147	159	154	160	162	151	161	161

GUIDELINES FOR THE DEVELOPMENT OF SIMULATION MODELS[1]

Dennis B. Webster[2]

Abstract. This paper discusses the chronological steps involved in developing a simulation model and presents guidelines to follow that are critical for successful model development. It is not intended to be an exhaustive treatment of the subject. Provided are practical insights into considerations of subjects and areas central to simulation modeling along with remarks concerning the make-up of the design team and members' responsibilities throughout the simulation project.

INTRODUCTION

Simulation projects are very difficult design tasks to plan, administer and conduct. Much has been written providing the necessary steps to follow and pitfalls to avoid. Shannon (1975, pp. 19-33), Law et. al (1982, pp. 43-46), Russell (1983, pp. 1-5 to 1-11). The author has also been part of an effort to explain considerations which must be confronted in a development effort. Hool et. al (1980). Reading such materials and even participating in the writing of one has not produced very rewarding experiences, at least to the degree that had been hoped.

In trying to develop the outline for this paper, I kept going back over my thoughts to see how I could present my points so that, if possible, the reader would be able to avoid the situations and mistakes that have hindered me. I do not know if I have succeeded. I do know that I am trying to relate to the reader in a succinct manner those tasks, points or whatever I believe to be initially important in successful simulation modeling. Some are more important than others, but all are necessary although not sufficient conditions to a successful modeling venture.

The approach taken is that of discussing the chronological steps generally followed in a simulation study as well as the parties that must be involved in each step. The author believes there are at least three distinct groups involved in any simulation study: (1) the simulation designers, (2) the design implementors, and (3) the users or result implementers. Each of these has a vital role to play with varying degrees of responsibility in each part of the simulation effort. In any particular simulation any individual may perform multiple tasks and thus could be considered a part of one or all of these groups. It is necessary, however, that every person clearly understands his responsibilities and role at each step so that he may contribute in relation to that dictated by group objectives of which he is a part.

This is not to imply that an adversary relationship exists among these groups - quite the contrary. But if, for example, the primary simulation designer is also a programmer (design implementer), there may be a tendency to hurry through model validation efforts, an area where the users (results implementers) should have primary responsibilities. These types of situations should be avoided if at all possible.

INITIALIZATION PHASE

The first steps in any design study always deal with activities such as

(a) Problem Definition,
(b) Definition of Objectives and Criteria.
(c) System Definition.

Without a doubt the largest single problem encountered in any simulation study is defining the problem. As with many problem solving approaches the difficulty lies in the fact that over time the focus of effort often evolves away from the initially defined problem. Likewise the "boundaries" on the problem environment or "system" if you will, also changes. These changes are natural to the evolutionary simulation process and are not something that should be resisted by the modeler, but they must be recognized for what they are - a means by which those involved with the process eventually arrive at a state where they really are convinced that they truly understand the problem at hand.

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[1]Paper presented at the conference COFE/IUFRO - 1984. Orono, Maine, USA, 12-14 August.

[2]Dennis B. Webster is Professor of Industrial Engineering, Auburn University, Alabama, USA.

The system designer, however, must track this process. The best way this can be done is to write down and periodically update three separate pieces of information: (1) Problem Statement, (2) Objectives and Criteria, and (3) Boundaries and/or Constraints on the problem. These are viewed in much the same way as Krick (1966, pp. 1-69) proposes them in general design work. As a general rule each should be reviewed and updated as required at least once per week initially and once per month thereafter.

The problem statement should be written down in no more than a one-half page description. Any more and it serves no useful purpose. The objectives must state what are desired to be achieved and the criteria state the means by which the attainment or non-attainment of the objectives will be measured. The boundaries and/or constraints on the problem specify the scope of the problem. The author maintains that without specifying each of these pieces of information, the problem is not defined, and one has no hope of specifying an adequate solution. It is also one way that can be used to avoid one of the cardinal sins of simulation modelers, "Failure to define an achievable goal." Russell (1983, pp. 1-5 to 1-11).

Relating this more specifically to timber harvesting modeling, the author believes that another way of asking these questions centers around the stated purposes of the model, Hool et. al (1980):

(a) What are the questions to be answered by the model?
(b) What are the performance variables of interest?
(c) What output is required?
(d) Are only mean values required or is distribution information needed?

Primary responsibility for the entire phase of this effort must rest with the system designers. This group must insure that the activities discussed above are adequately performed and coordinated among the design implementers and result implementers (users). The designer in this coordination effort will recognize that conflicting objectives and criteria may be defined among the groups. It is important that compromises be made which do not thwart the essential overall project's objectives with respect to any of the parties involved.

In the overall scheme of things this is the phase where the decision to develop a simulation model is often made. As a result of defining a very sizable and difficult problem, it is concluded that the only potentially feasible approach is simulation. This author does not agree with the often quoted remark, Bratley, et. al (1983, p. 33) "... the best advice to those about to embark on a very large simulation is often the same as Punch's famous advice to those about to marry: Don't!," but it is important to consider the necessity, importance of the results, costs, and feasibility of doing so.

Another extremely important task which must be accomplished in this phase of the study is the specification of the individuals forming the design team. This should not be done before any objectives are "set in concrete," but in reality is generally done at the time the decision to build a simulation model is made. The mix of this design team with appropriate skills in modeling, statistics, leadership, computer systems, and knowledge of the application area is vital. The ability to communicate as well as having respect for others' contributions is equally important. Each must understand the role or roles he is to play in the overall project as well as those played by everyone else.

Based upon these prefactory remarks the following guidelines and admonitions seem most appropriate.

(1) Commit to paper, i.e., write down the problem statement, objectives and criteria, and boundaries and/or constraints of the physical problem. The system design group should seek agreement from all parties. Seeking compromise, if necessary, is the responsibility of the system's design group.

(2) Alternate solution approaches should be evaluated. Simulation should be the last choice, and in fact, the only choice. If it is not, the reasons why not should be thoroughly explored by the systems design group.

(3) Evaluate simulation methodology in light of the defined objectives and criteria. It is especially important that achievable goals have been defined. All three defined groups have a vital interest here; it is important that each provide estimates of expectations and potential results, as well as estimates of necessary resource requirements (i.e., computer, time, data) to accomplish the objectives as outlined.

(4) If the decision is to proceed with the development of a simulation model, the systems design group must assemble individuals of the design team possessing not only the necessary technical skills, but also the "human and communication" skills for working on a joint simulation venture. There is no more vital element for successful project completion than this.

MODELING PHASE

At this point in time it is assumed that the decision to develop a simulation model has been made and the problem environment has been well defined. Now the work on actual system development can begin. Tasks that are required are:

(a) Model formulation
(b) Data preparation
(c) Selection of programming language
(d) Model development
(e) Coding of the model
(f) Model verification, and
(g) Model validation

As before and throughout this discussion, the reader is cautioned that although a chronological listing is presented, there is always much iteration taking place back and forth through the various steps. With this in mind, the model formulation step should be based upon the output from the Initialization Phase. The particular technological structures which made the particular model unique have got to be defined and integrated into a model structure which will provide answers to the questions which have been identified.

Integral to this step is deciding upon the level of detail to put into the model. Model complexity is not the same as model accuracy and the developer must understand as much as possible those factors which will influence the variables of interest in the simulation. This is a very difficult task which has no good solution approaches. One which has been used within the timber harvesting applications area is presented by Webster, et al. (1984). Related to the question of model detail is data specification, collection, and reduction for inclusion within the model. There is simply no use of specifying a detailed simulation model requiring detailed data, if it is not available, or cannot be obtained within reasonable time and cost constraints. Also there is no reasonable justification for specifying detailed data requirements for one aspect of the data, for example tree stand, if comparable detailed data is not available on the methods and/or times to harvest the stand, for example in the use of a feller buncher, if we were trying to simulate production data of that operation. There is no way that all variables of importance can be included within a simulation model. After all, the simulation is only a model of reality. The task (some say trick), therefore, is to isolate the major factors which input or influence the variables of interest and then adequately include them within the resultant model.

It is crucial at this stage that the ultimate user be made a part of these decisions. The designer must be careful to balance the constraints with necessary and desirable model features. The uniqueness and sensitivity of the system being studied must be embedded in the model, if a successful simulation effort is to result.

In conjunction with these tasks the design implementer group also must consider the specification of the programming language and starting actual model development. It is possible to find articles which supposedly compare various programming languages, including special simulation languages. These may be helpful, but are usually so only in a general fashion. There is certainly no one right answer for most applications, and this author maintains that for a given situation many alternatives are acceptable. This is not a universal view, however, Russell (1983).

One relatively new idea that has been proposed related to the question posed about the complexity of the model and the programming language selected to deal with it is that by Cellier (1983). Basically he proposes that the data management aspects of the model be separated from the programming language itself. This is beyond the technological logic-structure logic ideas proposed by Pritsker (1969, pp 14-15) in that all simulation languages possess these properties. Cellier believes that a simulation system should have a special data base management system adapted to the simulation's specific needs and has referenced Standridge (1981) to indicate such a system. The primary advantages of this approach are related to the ease of data collection, manipulation, and analysis within the model, but it has the trade off of added complexity introduced by the data management system itself.

My true feelings are that, except for the "hard-core" simulation modeler, the selection of the language depends more upon the constraints placed upon the situation and modeling environment than upon anything else. Answers to such questions as the following will probably decide the question: Who will be doing the programming? What languages do they know? What computer system will it run on? What documentation and assistance are available? How much time is there to complete the task? Is this a one time analysis or part of a continuing modeling effort?

Once the programming language and model formulation has been specified, the coding of the model along with verification of it can be accomplished. This should be a straightforward process, but this author has never seen an example where this has been the case. There have been many strides made recently in coding strategies and documentation procedures, but this is still an area where only little effort initially will reap future headaches. Programming like simulation itself, is some science implemented with a lot of art. Ignoring this, or expecting that the coder knows what he is doing on the part of the designer will surely create hazardous if not disastrous consequences. It is at the coding stage, no matter how complete the model formulation and design is, that a multiplicity of assumptions get built into the simulation model. Without excellent communication and the exercise of control over the coding efforts among the coder, the designer and the user, there is little hope that the result will be as any one of these expects, except the programmer.

With these brief remarks, the following guidelines or principles seem in order:

1. Make the model as independent as possible with respect to computer systems, languages, application packages, and operating systems, if the model is to be used more than once or by different user groups.

2. Make the model as "user friendly" while at the same time as "foolproof" as possible. This can be done partially by developing interactive data inputs, preassignment of many or most parameter values, and developing pre and post processor add-ons for data input, analysis and output.

3. Use "standard" approaches to design and programming. Top down, structured programming as well as documentation procedures are recommended.

4. Develop alternate levels of documentation (for different levels of user understanding and potential use) so that appropriate materials exist for each expected class of user.

5. Keep the number of programmers to a minimum. If there must be two or more programmers, the task must be broken into logical units with each assigned to a separate unit.

6. Programming, once started, should be a full time task. If this is not feasible, then at least full time effort must be expended on each logical unit until each is completed.

7. Implement the "document or die" philosophy. No unit of the model should be considered complete until all appropriate levels of documentation have been completed. This should be the responsibility of both the coding and user groups, but closely monitored by the systems design group.

8. Verification of the coding should be completed first by the programmers, then independently, if possible, by the users.

9. Periodic meetings, I suggest weekly, should be held throughout this phase between the designers, programmers, and users to ensure that each understands the progress as well as the constraints being embedded within the model. Each group has its own responsibilities and desires and each should use this forum to convey these to the others.

10. Validation of the model, although being performed all along, should be executed specifically with respect to the objectives and criteria established in the Initialization Phase. The user group would have primary responsibility for this activity.

11. Validate the model with respect to the designed objectives of the simulation. If the model cannot be validated with a high degree of confidence, either the objectives and criteria will have to be changed or additional complexity added to the model.

12. Keep the simulation model as simple as possible within the constraints of model objectives and criteria.

IMPLEMENTATION PHASE

This last phase determines whether or not all previous effort has been in vain. Tasks which must be accomplished include:

(a) Strategic planning
(b) Tactical planning
(c) Experimentation
(d) Analysis of results
(e) Decisions or indications obtained by the model, and
(f) Follow up studies.

Strategic planning involves determining the overall experimental design that may be used in development and use of model results. Tactical planning is the detailed planning such as determining sample size, run length, and initial conditions for startup of the simulation model. Experimentation is the actual exercising of the model and collection of the output. The analysis then includes data reduction, completion of the overall design methodology and summarization of the results. Based upon these results, decisions can hopefully be made which relate to the overall study objectives, followed by an audit or post analysis to check if the simulation study produced the quality and quantity results that were forecasted.

Contrary to popular opinion of most academics, very few simulation studies fail because of what is done or not done within this phase. And if errors do occur, they are almost always forgiving, in that they can be corrected without altering the integrity of the simulation itself. To be sure, this is still a very important step with respect to whether usable results are generated by the developed model, but it is also the phase where any necessary changes can most readily be made.

For example, if an inappropriate experimental design was used in generating results for an objective, a new one could be developed and new simulation runs made. If inappropriate startup conditions were used by the model, or if the model run lengths were not long enough to develop smoothed distributional data, the runs could be performed again. This is not to suggest that such errors might not cause one to spend large amounts of time and resources in correcting errors which might be found, but only to suggest that these are often much easier to do something about than errors which may have been generated in either of the two preceeding phases.

It is also one reason why a follow-up study provides the whole process with a self-correcting feature. By checking to see whether system objectives were met and within those limits estimated at the startup, one is forced to critically examine the results of the simulation efforts. This checking process will thus ensure through its own analysis that the model is being used appropriately. It is also a way to document the worth of any results obtained, which may be useful in estimating the potential of future or related simulation efforts.

With these thoughts in mind, the following guidelines are felt to be important:

1. If implementation of results is not built into the overall project time frame, do not start the modeling process. It is also a common mistake to allow inadequate time for implementation of results.

2. The members of the design team, i.e., users, designers, and programmers, should not change, insofar as this is possible during the entire study. Such changes can have subtle though tremendously far reaching effects on the project's outcome.

3. Once the simulation model is completed, the analysis finished and conclusions drawn,

provisions must often be made for continued support of the model. Situations which require additional model runs, minor modifications, further documentation, additional explanation, etc., ad nauseum, often occur after everyone thought the work was completed and are vital to ensure the project's success. Plan for it in the beginning.

SUMMARY

This paper presents ideas and guidelines which are necessary for the development of worthwhile simulation models. It is not intended to be exhaustive in its coverage. Even faithfully following the intent as well as the guidelines themselves will not guarantee that any venture the reader may undertake will be successful. Not following them, however, will ensure project failure. Therefore, they are presented only for the purposes of communicating to the reader the vital necessity of thorough planning, detailed and watchful execution, and persistence in all phases of the simulation study. Simulation is an extremely powerful and useful tool, but with its use come many pitfalls which can be avoided. The simulation modeler cannot count on luck, but only on his diligence, training and experience to prepare himself. Hopefully, the guidelines presented here will help focus his attention upon areas and concerns deemed critical in model development.

LITERATURE CITED

1. Bratley, Paul, Fox, B. L. and Schrage, L. E. 1983. A Guide To Simulation, Springer-Verlag, New York, N. Y.

2. Cellier, Francois E., 1983. "New Problems in Software Complexity," Simulation, Vol. 41, No. 9, September, pp. 118-119.

3. Hool, J. N., Webster, D. B., and G. S. Hines, 1980. "Considerations in Developing/Selecting a Timber Harvesting Simulation Model," Proceedings of the 1980 Summer Computer Simulation Conference, August 25-27, 1980, pp. 461-464.

4. Krick, Edward V., 1966. Methods Engineering, John Wiley and Sons, New York, N. Y.

5. Law, Averill M., and Kelton, W. David, 1982. Simulation Modeling and Analysis, McGraw-Hill Book Company, New York, New York.

6. Pritsker, A. A. B. and Kiviat, P. J., 1969. Simulation with GASP II, Prentice-Hall, Inc., New York, New York.

7. Russell, Edward C., 1983. Building Simulation Models With SIMSCRIPT II.5, Consolidated Analysis Centers, Inc., Los Angeles, California, pp. 1-5 -1-11.

8. Shannon, Robert E., 1975. Systems Simulation: The Art and Science. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

9. Standridge, C. R. and Wortman, D. B., 1981. "The Simulation Data Language (SDL): A Database Management System for Modelers," Simulation, Vol. 37, No. 2, August, pp. 55-58.

10. Standridge, C. R., 1981. "The Simulation Data Language (SDL): Applications and Examples," Simulation, Vol. 37, No. 4, October, pp. 119-130.

11. Webster, D. B., Padgett, M. L., Hines, G. S., and Sirois, D. L., 1984. "Determining the Level of Detail in A Simulation Model - A Case Study, Computers and Industrial Engineering. To be published.

RECENT RESEARCH AND DEVELOPMENT OF ANCHORING SYSTEMS FOR CABLE LOGGING OPERATIONS[1]

Ronald L. Copstead[2]

Abstract.--Stumps required for cable logging tailhold and guyline anchors are not always available or strong enough. This paper describes three ongoing USDA Forest Service projects aimed at solving this problem. The importance of predicting the pullout resistance of stumps, the requirements for substitute anchors, and the development of substitute earth anchors are reviewed.

INTRODUCTION

The lack of practical solutions to cable logging anchoring problems will soon have a noticeable impact on timber management activities in the National Forests. In 1976, about 10 percent of the Forest Service sale volume in the western United States required some form of substitute anchoring scheme. That estimate has risen to about 13 percent.[3] These needs are becoming apparent as new landings are planned adjacent to old clearcuts where stumps and their roots have rotted and new growth is not large enough to provide good anchors. Also, there is an increasing tendency to plan harvesting units in low volume stands where stumps adjacent to potential landing sites are not adequate to use as anchors.

These problems have been recognized for years by the Forest Service. Prior to 1982 the Equipment Development Center at San Dimas, California, conducted many studies to find out what loads are imposed on anchors, what substitute anchoring systems are available, and what the capabilities of these anchoring systems are. The Engineering Research project at the Pacific Northwest Forest and Range Experiment Station in Seattle organized tests at Snoqualmie Falls, Washington (Jorgensen et al. 1978) to determine loads on anchors and in 1980 began a study to determine the feasibility of helical screw anchors for cable logging application.

The Forest Service now has two research studies in anchoring sponsored by the Pacific Northwest Forest and Range Experiment Station, and a single large research and development contract administered by the Equipment Development Center. Table 1 gives the titles of these programs along with the sponsoring organization, the organization doing the work, and the approximate completion date.

This paper summarizes the programs listed in table 1; however, to put these programs into perspective, I will review characteristics of various anchoring methods for cable logging. Formal disclosure of research results is not the purpose here. Results will be published as the programs are concluded.

TYPES OF ANCHORS

Four types of anchors have been used for cable logging operations: stumps, rockbolts, substitute earth anchors, and deadweight-equipment anchors. The use of stump anchors is common practice. They are always the lowest cost anchors unless there is doubt about their pullout resistance. Where there is doubt about the strength of single stumps, tieback lines that bring several stumps together in a multiple-stump anchorage are commonly used. This type of anchorage is more costly than a single stump but generally less costly than a stump substitute. A method for more accurately determining the pullout resistance of stump anchors is the subject of an Engineering Research project study that is discussed below.

[1]Paper presented at the conference COFE/IUFRO - 1984. Orono, Maine, USA, 12-14 August.
[2]Ronald L. Copstead is a mechanical engineer with the USDA - Forest Service, Pacific Northwest Forest and Range Experiment Station, Seattle, Washington, USA.
[3]An informal survey conducted among 32 Forest Service logging specialists from the western United States in June 1984 indicated that about 13 percent of timber volume that could be harvested during the next 5 years with cable systems need substitute anchors.

Table 1.--USDA Forest Service ongoing anchor programs

Program title	Organization	Completion
Pullout resistance of guyline stumps	Pacific Northwest Forest and Range Experiment Station, Oregon State University	1985
Anchoring requirements for cable logging in southeast Alaska	Pacific Northwest Forest and Range Experiment Station	1985
Substitute earth anchoring system	San Dimas Equipment Development Center, Foster-Miller, Inc.	1985

Although rockbolt technology is well developed and widely used in the construction and mining industries, rockbolt anchors are not used much for logging, primarily because of the high cost of design and installation. Several factors contribute to this. Rockbolt installations require a good understanding of the geology, rock material, and expected applied loads for each situation. For instance, the size, spacing, and orientation of rock discontinuities must be assessed. Rock strength must be estimated. The more precisely the on-site conditions are evaluated, the more confidence there will be in the rockbolt installation. This is important for rockbolts because, in contrast to earth anchors and stumps, failure is usually catastrophic and preceded by little warning. Some development work needs to be done to reduce the cost of site investigation and rockbolt anchorage design and still assure safe and reliable installations. Because the technology is well developed and because shallow soils are prevalent in many cable logging locations, rockbolts could become important as substitute anchors in the future.

An example of a deadweight-equipment anchor is a crawler tractor with the blade dug into the ground and to which the cable to be anchored has been attached at the belly hook. Such anchors are often used to great advantage as mobile tailhold anchors. This type of anchor, however, cannot be used where the cable to be anchored is pulling the equipment down a steep slope or where the equipment cannot gain access to the desired location. This type of anchor may or may not be the most economical. Because the cost of this method depends heavily on the local availability of depreciated capital equipment, cost estimates often cannot be made by timber harvesting specialists at the planning stage.

Deadman anchors are a specialized type of substitute earth anchor. Prellwitz and Lee (1977) give a procedure that can be used by a nonspecialist to design a deadman anchor installation that will always be conservative. Deadman anchors are currently the most common substitute earth-anchoring technique used in cable logging operations. They cannot be used, however, on steep slopes where the cable to be anchored is pulling downhill or where access cannot be gained by the large excavating equipment necessary. Also, the extensive excavation required results in high costs for installing deadman anchors. Earth anchor substitutes other than deadman anchors are the subject of the San Dimas Equipment Development Center contract discussed later.

In summary, stumps are always the most economical anchors if their safety can be relied on. Deadman anchors and deadweight-equipment anchors are feasible stump substitutes in many situations, although their cost-effectiveness cannot always be assured. In areas of very shallow soil where there are no reliable stump anchors, rockbolts may be the only answer.

RESEARCH AND DEVELOPMENT OBJECTIVES

When a timber sale is planned and laid out, many factors must be considered. An important guideline during this process is to minimize the combined cost of planning, roadbuilding, and harvesting. In areas designated for cable logging, if stump anchors are not available or they are believed to be inadequate, the logging plan must be changed or substitute anchors must be specified. In most cases where substitute anchors are specified, detailed information must be obtained regarding the soil or rock conditions at the anchor sites. Additionally, it is necessary to gain access with installation equipment to each substitute anchor location. Because of this, it is clear that planning and harvesting costs will increase if substitute anchors are required. The primary objectives, then, for research and development on anchors are: (1) to reduce the number of situations that require substitute anchors by learning more about stump pullout resistance and (2) to devise substitute anchoring methods that minimize increases in the combined cost of planning, roadbuilding, and harvesting.

RESEARCH ON STUMP ANCHORS

Generally, stumps are thought of as being in one of three categories in their ability to safely anchor yarding machinery: (1) capable of withstanding anchor loads, (2) may or may not be capable of withstanding anchor loads, and (3) not capable of withstanding anchor loads.

As timber sales involve more small timber, more stumps with questionable pullout resistance will be encountered. If the pullout resistance of stump anchors can be predicted more precisely, the number of situations that are questionable will be reduced. Timber management professionals can then reduce the number of situations for which they must consider specifying substitute anchors.

As indicated in table 1, research at Oregon State University is aimed at determining the pullout resistance of stump anchors. To date, approximately 20 second-growth Douglas-fir stumps with diameters ranging from 6 to 17 inches have been pulled to their maximum load-bearing capacity. Loads, stump movement, soil properties, and a detailed description of the tree and its root wad were recorded. This study will be followed by an investigation into the pullout resistance of spruce and hemlock stumps and a study on the pullout resistance of multiple-stump anchors.

To the present, the data for this study have been recorded and plotted as load versus movement of the stump. There has been no attempt to define failure criteria for a stump anchor. Indeed, failure criteria for anchor tests have been more or less arbitrary. Certainly, the maximum load that an anchor will withstand could be termed its failure load. But in practice logging operators consider that an anchor has failed at some load substantially less than the ultimate pullout load. Until common agreement can be reached on the failure criteria for anchors, the most useful data will be load versus movement curves.

These studies are important because people involved in the initial phases of timber harvest planning must determine if substitutes for stumps will be needed. In practice, the load that a specific stump can safely withstand may never be predicted with absolute certainty. Studies such as this, however, will reduce the number of situations where higher cost substitute anchor designs must be specified.

REQUIREMENTS FOR SUBSTITUTE ANCHORS

Where stumps are inadequate or nonexistent, it is important to identify the technical requirements of substitute anchors as specifically as possible so that research and development can be carried out most effectively. Also, it is important to estimate costs of the anchoring systems required because this will affect timber management planning decisions. Many anchoring and anchor installation schemes have been devised over the years for purposes other than anchoring cable logging systems. In contrast to these, cable logging anchors: (1) must withstand relatively high static and dynamic loads; (2) require margins of safety comparable to other devices where human life is at risk; (3) have a very short useful service life (i.e., less than 1 year); and (4) must be installed despite difficult soil, rock, and terrain conditions.

These four general characteristics are sufficient to distinguish cable logging anchors from anchors used by other industries (e.g. the electric power utilities). The characteristics of substitute anchors required for Forest Service timber sales, however, can be further refined. A formal study to delineate the requirements for substitute anchors is described below.

Anchoring Requirements for Cable Logging in Southeast Alaska

The intent of the second study listed in table 1 is to determine the need for substitute anchors in three areas of southeast Alaska. The study will also determine the predominant conditions pertinent to substitute anchoring for these areas.

Three logging and transportation plans (covering approximately 85,000 acres) are being analyzed on a setting-by-setting basis to characterize prevalent anchor problems. Data such as elevation, landform position, percent slope, slope aspect, soil or rock type, and an estimate of the number of missing anchors are being obtained for the planned landing and tailhold locations. From these data and from field verification, sites that have a high likelihood of presenting cable logging anchoring problems can be enumerated and characterized.

Although this study is still in progress, it is clear that the characteristics of substitute anchors needed in southeast Alaska can be specified much more closely than with the four general requirements stated above. For instance, it appears that the majority of problems are along the tops or shoulders of ridges where shallow, rocky soils are common and guyline anchors would be involved rather than tailhold anchors. The type of soil bears heavily on the anchors required, and the terrain limits the methods used for installation. Ultimately the total planning and harvesting costs are affected.

Researchers and forest managers can use this information in the short term to set priorities for anchor research and development. Follow-up studies to monitor how well the initial estimates of anchor problems correlate with problems actually encountered during harvesting will result in better predictions of the number, type, and cost of dealing with the problems.

SUBSTITUTE EARTH ANCHORING SYSTEMS

Where stumps are not available for anchoring, and deadweight-equipment, deadman, or rockbolt anchors are not feasible or are too expensive, substitute earth anchors must be specified. For the purposes of the project discussed below, earth anchors are defined as anchors that can be installed in soils with standard penetration test blow-count values of 100 blows per foot or less. (The standard penetration test is described below.) In practice, this means that earth anchors cannot be installed in soft rock, weathered rock, or hard rock soils.

The San Dimas Equipment Development Center has contracted with Foster-Miller, Inc., in Waltham, Massachusetts, to conduct an extensive study into earth anchoring technology. In addition to the engineers at the Center, National Forest System logging engineers, representatives from Research, and Aerospace Corporation are serving as technical reviewers and advisors for the work. Foster-Miller, Inc., is providing overall management of the project along with most of the design and development engineering. They are subcontracting specialized geotechnical and logging engineering work to other firms.

Work on this contract is divided into four major tasks:

1. Dynamic Analysis and Test of Skyline Logging Systems. The objective of this task is to develop an improved understanding of the dynamic behavior of skyline logging systems, so that the load requirements for substitute anchors can be specified.

2. Anchor Testing Equipment. The objective is to develop equipment for testing the holding capacity of anchors under the full range of static and dynamic loads that could be imposed by a cable logging system. This equipment is intended only as a development tool to determine if the anchors meet their design requirements.

3. Soil Testing Equipment and Methods. The objective is to provide equipment and perhaps new methods to determine soil conditions at a proposed installation site.

4. Substitute Earth Anchor System. The objective is to develop anchor systems, including anchors, soil testing apparatus, installation equipment, field testing and transportation equipment, and design manuals.

Substantial progress has been made since these tasks were begun in October 1982. We now have a reasonably clear understanding of the nature of cable logging dynamic loads, an anchor testing machine that has just completed its initial checkout tests, a fairly complete design for a soil testing method, and several earth-anchor concepts that show promise for solving a variety of problems with substitute earth anchors.

Although the goal of this work is to develop an earth-anchoring system, many of the results concerning design loads, installation equipment, and its transportation to the anchor site are equally applicable to rockbolt anchors. Indeed, one of the goals of the Pacific Northwest Forest and Range Experiment Station Engineering Research Unit is to extend the Equipment Development Center work to soil conditions requiring rockbolts.

Cable Logging Anchor Loads and Anchor Testing Equipment

An improved understanding of the characteristics of loads that cable logging anchors must withstand was necessary before testing equipment could be designed and built. The maximum static load that anchors would have to withstand was specified as the breaking strength of the wire rope for which the anchor is designed. Static loads, however, may not be the most severe loading situation to which a substitute earth anchor is subjected. Based on the Snoqualmie Falls tests (Jorgensen et al. 1978), it was believed that large loads could be transmitted to anchors at frequencies up to five Hertz (cycles per second). This type of cyclic loading could cause earth anchors to fail at peak loads less than their design static loads because of cyclic creep of the soil. Whether cyclic creep occurs or not apparently depends on the properties of the soil and the nature of the cyclic loads (Kovacs and Yokel 1978). When subjected to vibratory loads, the soil strength is less than under static loading. To quantify the cyclic loads generated by cable logging equipment, a mathematical model was formulated and measurements were made of the loads on anchors in a typical operating cable logging system. A brief summary of the model follows; details will be published elsewhere.

The mathematical model is a simple two-degree-of-freedom representation of a cable yarder consisting of a vertical tower, guyline cluster, skyline, and log load. The guylines and tower are considered to be one spring-mass system, while the skyline and log load are modeled as another spring-mass system. The spring behavior of the tower-guyline system is calculated with the aid of a guyline analysis model developed by the Forest Service (Carson et al. 1982). An elastic catenary model of the skyline extension and contraction gives the spring constant for the log load component. This information is then used to calculate the two natural frequencies of the modeled skyline system. The limitation of this model is that it cannot predict load frequencies higher than the first two fundamental modes. Presently, these modes appear to occur at two Hertz or less for any reasonable skyline system. The model assumes that no damping is present, and therefore, that all loads act in phase or 180 degrees out of phase with each other.

Results from the Snoqualmie Falls tests (Jorgensen et al. 1978) indicate that such a model may be able to adequately describe the important dynamic characteristics of anchor loads because the damping in such cable systems is extremely small, and the basic vibrational frequencies are dictated by the skyline geometry and the log load.

Frequencies predicted by the model just described are being compared to the measurements taken in 1977 at Snoqualmie Falls (Jorgensen et al. 1978), and to those taken in 1983 at Dry Creek near Shelton, Washington.[4]

The intended use of the anchor testing equipment is to test anchors under conditions similar to what they will encounter in service. Because of this, results from the tests conducted during 1983 and the increased understanding gained from initial study of the mathematical model have been used to specify the design for this machinery.

The anchor load data recorded during field tests were analyzed by Aerospace Corporation using a frequency spectrum analyzer. From this work the relative magnitudes of dynamic load variations at different frequencies can be determined. A summary of this information along with the anchor testing equipment design specification for dynamic load amplitudes (marked "ATE design") is shown in figure 1. The measured loads and the anchor testing equipment design loads can be compared on the same relative scale if the highest measured load level is assumed to coincide with the highest test load of interest.

The reader should note that the y-axis in figure 1 has a logarithmic scale and is delineated in decibels (dB). This means that all the values are plotted as a function of their relationship to a reference level; in this case, the load level

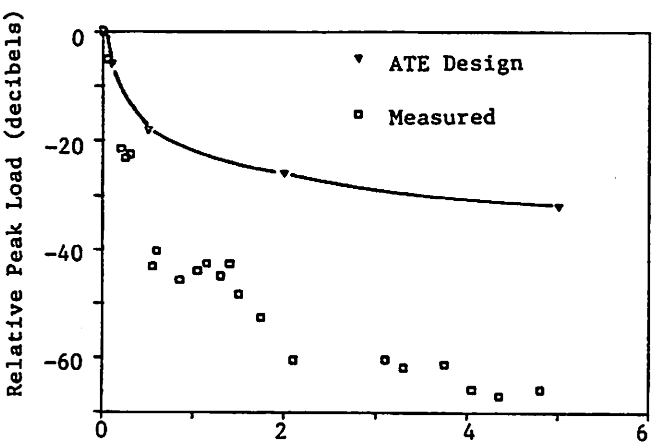

Figure 1.--Measured guyline dynamic loads and anchor testing equipment (ATE) design dynamic loads versus frequency.

[4]Unpublished data on file, Forestry Sciences Laboratory, 4043 Roosevelt Way N.E., Seattle, WA 98105

that occurs at 0 Hertz (hz). For example, differences of 6 or 20 decibels between two data points would mean that the load levels differ by factors of 2 or 10, respectively, on this plot.

Figure 1 shows that the current design specification for the dynamic loading portion of the anchor testing machinery is very conservative with respect to what we know about the dynamics of cable logging systems.

The static load specification for testing anchors is the breaking strength of the cable for which the particular anchor is designed. For anchors designed for cables up to 2 inches in diameter, the anchor testing machine will pull up to 400,000 pounds.

Currently the main frame of this machine has been fabricated, and an initial checkout of the hydraulic system has been made. Testing will soon begin on candidate earth anchors using the machine in the Massachusetts area. The checkout tests are being conducted in a granite quarry near West Chelmsford, Massachusetts.

Soil Testing and Anchor Installation Equipment

Early in this program an extensive search of the literature about earth-anchoring concepts was performed by Foster-Miller and their geotechnical subcontractor, Shannon-Wilson. This investigation led to several conclusions that have guided the remainder of the work. One conclusion was that there are no single anchors that will develop the desired holding capacities of over 200,000 pounds. This means that several "small" anchors will have to be bridled together to form a single anchorage. Efforts have thus been concentrated on developing anchors with holding capacities up to 70,000 pounds. The soil depth and strength in a particular location will dictate the number of anchors to be bridled to achieve the desired total anchor capacity.

A soil testing device is required for assessing the strength and depth of the soil in a particular location. After much investigation of various soil testing devices and methods, the standard penetration test (SPT) was determined to be best suited to this task.

The SPT is a simple device requiring a minimum of equipment and training. The equipment consists of a 140-pound weight that is allowed to fall 30 inches--causing the penetration of a sampling tool of certain dimensions into the soil. The procedure is to record the number of blows to advance the sampler each of three 6-inch intervals into the soil. The result of the test is the blow count (in units of blows per foot) and is taken as the sum of the blows required to advance the final two intervals. Sometimes the soil from the sampler is qualitatively evaluated.

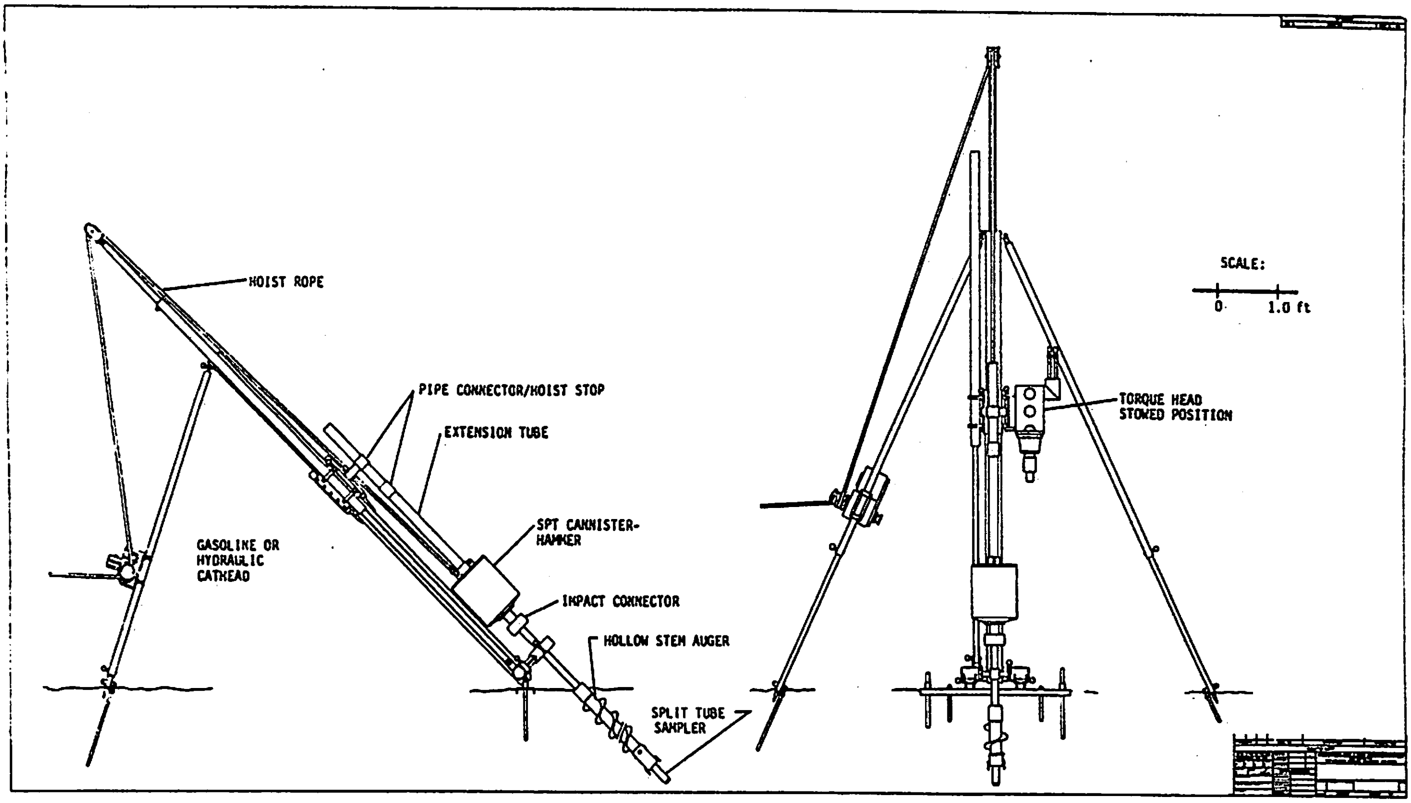

Figure 2.--Proposed soil testing and anchor installation apparatus.

Besides its simplicity, the SPT was chosen because the blow count has been correlated with more soil properties than have the results of any other test. Although many of the correlations are crude and few have any theoretical basis, typically they are conservative in anchor pullout resistance.

Foster-Miller has designed and is beginning to build an integrated soil testing and anchor installation rig (fig. 2). Provisions for the SPT have been designed into this equipment. This machine consists of a separate hydraulic power unit, a tripod supported mast, a hydraulic cylinder to provide thrust and retraction power, a hydraulic torque head, and a hydraulic control system. The machine is a general purpose unit capable of operating augers, rock drills, and an auxiliary cathead for the SPT hammer. A typical operational sequence would be:

1. Transport the test and installation rig to the potential anchor site. The equipment is designed to break down without tools into pieces weighing 75 pounds or less except for the torque head (120 pounds). The hydraulic power unit is placed at a central location and is not transported to each anchor site.

2. Unfold the rig, set up its tripod structure, and anchor the legs with small screw anchors.

3. Connect the hydraulic hoses to the cylinder, torque head, or cathead and start the hydraulic power unit.

4. Perform either conventional or hollow-stem augering.

5. Perform the SPT either through the hollow-stem auger (in collapsing soils) or simply in the augered (free-standing) hole.

6. Remove the soil testing attachments and install the anchor with the aid of either torque or impact energy from the rig.

Off-the-shelf systems were found to be either inadequate in torque or thrust, or they weighed too much to meet logistical constraints for in situ soil testing and anchor installation in mountainous forest terrain.

Substitute Earth Anchors

Throughout the contract, anchoring methods have been studied to evaluate their applicability to cable logging systems. Factors that have been considered are: (1) the load-bearing capacity and range of loading angles, (2) the types of soils that an anchor can be installed in, (3) the installation forces and equipment required, (4) the weight of the anchor, and (5) the cost of fabrication and installation.

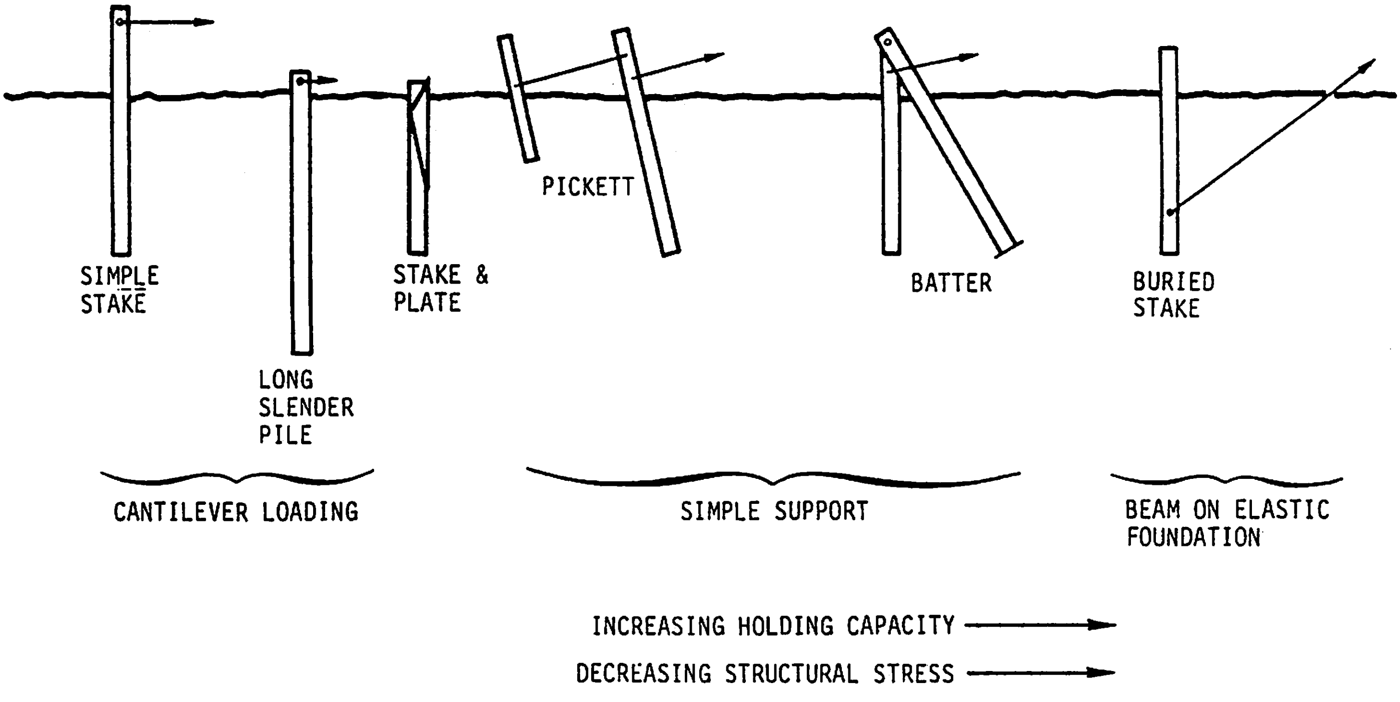

Figure 3.--Laterally loaded pile anchors.

About 20 concepts have been reviewed. They can be grouped, however, into a few broad classes which are discussed below. The information reported here is based primarily on vendor catalogs, some preliminary analyses, and tests reported in the literature. The next step is to conduct trial tests of some of these concepts to get actual field data on the factors listed above.

Laterally Loaded Piles

A laterally loaded pile is a stake that is loaded at right angles to its long axis, shown at the left of figure 3. This method is used extensively in the construction industries and many other applications. It has the advantage of simple structure and straightforward installation. Piles can be installed in soils of all densities including some rocky soils. Their disadvantages include difficulty in predicting their behavior under load, low load capacity compared with other anchors of the same size and weight, and large energy requirements for installation. The load capacity is limited because the pile has to withstand cantilever bending loads. Large pile cross sections must be used to withstand the large bending moments caused by bending loads. To install piles with large cross sections requires large pile drivers. The conclusion is that conventional laterally loaded piles are not suited for use as cable logging anchors because of difficulty in transporting large installation equipment to each site.

Variations of the simple stake method that show promise for use as cable logging anchors are shown toward the right in figure 3. The most promising of these variations are the picket, the batter pile, and the buried stake. The advantage of these methods is that instead of the cantilever loading of the simple stake, they are loaded as a simply supported beam. They can, therefore, be much lighter weight for the same holding capacity. Each, however, has the disadvantage of being more difficult to install.

Plate Anchors

Plate anchors are a broad class that includes helical screw anchors, folding anchors, and tipping-plate anchors. Ultimate pullout resistances for all these anchors are calculated by use of techniques that are similar and that are based on soil bearing-capacity factors. These anchors are lighter weight for a given load capacity than the pile anchors discussed above. Their installation is generally restricted to loose or only moderately dense soils. Installation techniques include pile driving for the tipping-plate anchors, high torque and down-pressure for the screw anchors, and augering a clearance hole for many of the folding anchors.

Most plate anchors can probably be designed, by use of a flexible connection to the major load bearing surface (fig. 4), so that their load capacity is not sensitive to load angle. The wire rope in figure 4 passes through a drive tube that transmits the thrust and torque required for installation to the anchor. After installation the tube is removed, and the free end of the rope is terminated with wire rope clips.

Of the plate anchor methods reviewed, the screw anchors and folding anchors seem to hold the most promise. There are several designs commercially

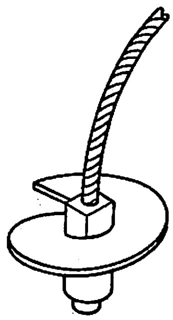

Figure 4.--Flexible connections for plate anchors minimize alignment requirements.

available that could be modified to suit the requirements of cable logging anchoring. Foster-Miller, Inc., has completed the preliminary design of a family of "hinge-plate" anchors that would be installed in augered holes (fig. 5). This anchor can be fabricated easily (by use of a cutting torch and a drill press), requires minimum installation energy, and has the potential for relatively high holding capacities.

Soil Nets

The net concept (fig. 6) is a variation of the deadman anchor system; it is particularly suited to cohesionless soils, weak organic soils, and shallow soils. The net is constructed of either steel mesh or synthetic fabric and is trenched into the soil. The holding capacity is derived from the mass of soil contained by the net and from the shear resistance along a failure plane extending in front of the net wall. Several factors may preclude the consideration of this concept. This type of anchor is restricted to pull angles that are almost parallel with the ground plane. The load must be transmitted evenly to all elements of the net, and vertical load components to the net must be eliminated without trenching in critical soil-failure-zone areas

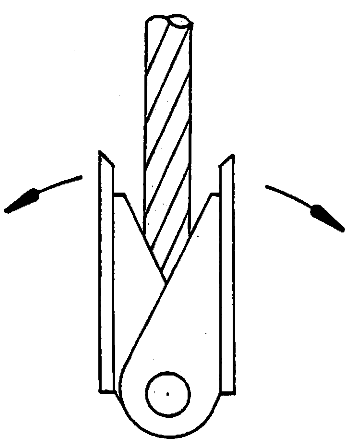

Figure 5.--Hinge-plate anchor.

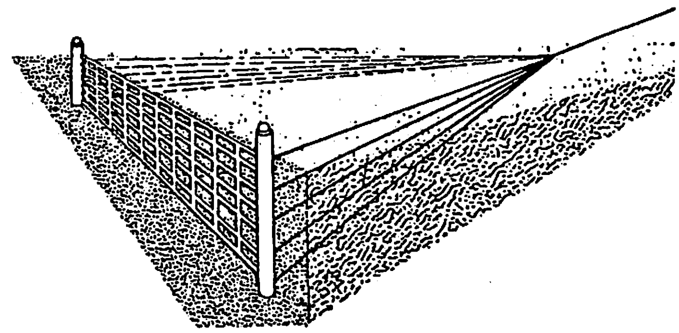

Figure 6.--Soil-net anchor concept.

(fig. 6). The trenching required for installation is not as expensive as that for deadman anchors, but it still may render this concept unsuitable for consideration as a cable logging anchor. If this concept is developed, however, it could be the answer for shallow soil situations.

Grouted Soil Anchors

Grouted soil anchors consist of a steel tendon placed into a hole and then grouted with cement. The holding force is transmitted through the tendon, which can be a steel cable or deformed bars, to the grout-soil interface. This is really no different from a grouted tendon in rock, except that the reduced strength of the soil material requires that a much larger grout cylinder be installed to attain a comparable holding capacity. Foster-Miller, Inc., reports that 2.8 cubic yards of grout are needed to provide a 200,000 pound anchor in moist sand with an SPT blow count value of 20.[4] Great amounts of water and grouting compound must be transported to each earth anchor site. Although this type of anchor is used extensively for permanent tiebacks in the construction industry, the feasibility of its use for cable logging is questionable except in very dense soils. It should be noted that grouted tendons deserve consideration as substitute anchors in soft or hard rock.

SUMMARY

Stumps have always been the most convenient, the least expensive, and therefore the most widely used anchors for cable logging machinery. In more and more areas, however, there are no sound stumps of adequate size, properly located relative to yarder landings. Older large stumps and their root systems are rotting, and new stumps are often smaller than required for anchoring cable machinery. The objectives of research and development for

[4]Foster-Miller, Inc. 1984. SEAS Concept Design Report. Document FSS8266-R-016. Unpublished report. Foster-Miller, Inc., 350 Second Avenue, Waltham, Massachusetts 02154.

easing these problems are to gain a more precise understanding of new stump pullout resistance, and to increase our knowledge of substitute anchoring methods that minimize the increased planning and harvesting costs that nonstump anchors will inevitably incur.

The Engineering Research unit of the Pacific Northwest Forest and Range Experiment Station is sponsoring studies on the pullout resistance of stump anchors and on requirements for substitute anchors in southeast Alaska. Results from these studies will help forest managers design least cost solutions for what are considered anchoring problems today.

The San Dimas Equipment Development Center is managing a comprehensive contracted effort to develop substitute earth anchors. This program will provide solutions in situations where stumps are inadequate or nonexistent, rockbolts are inappropriate, and deadweight-equipment anchors and deadman anchors are impractical or too costly.

LITERATURE CITED

Carson, Ward W., Jens E. Jorgensen, Stephen E. Reutebuch, and William J. Bramwell. 1982. A procedure for analysis of guyline tension. USDA Forest Service General Technical Report PNW-142, 45 p. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

Jorgensen, Jens E., Ward W. Carson, James D. Chalupnik, and Joseph L. Garbini. 1978. Skyline anchor dynamics test. Technical Report FE-UW-7702, 74 p. USDA Forest Service, Equipment Development Center, San Dimas, Calif.

Kovacs, William D., and Felix Y. Yokel. 1979. Soil and rock anchors for mobile homes - a state-of-the-art report. 164 p. U.S. Department of Commerce, National Bureau of Standards Center for Building Technology, Washington, D.C.

Prellwitz, Rodney W., and H. J. Lee. 1977. Deadman anchors. Project Record, 58 p. USDA Forest Service, Equipment Development Center, San Dimas, Calif.

NON-SHEAR FELLING MACHINERY IN BRITISH COLUMBIA[1]

Bruce A. McMorland[2]

Abstract.--This paper traces the introduction and development of non-shear felling machinery in Interior British Columbia, Canada. More than fifteen makes of non-shear felling heads are identified, and problems of introduction are noted. A felling-damage measurement technique is explained, and results from studies using the techniques are provided.

INTRODUCTION

The Province of British Columbia (B.C.) on Canada's west coast is naturally divided into two distinct climatic zones by the coastal mountains. The coastal zone is characterized by a year-round mild climate, steep and rugged topography, and large trees. The Interior has hot summers and cold winters, a large variety of terrain conditions, and smaller tree sizes. Coastal harvesting is normally with highlead towers or other cable-yarding systems. In the Interior, gentler slopes and smaller trees permit a wider range of systems.

B.C. accounts for 42% to 50% of Canada's roundwood production (Environment Canada 1984). In 1981, Canada produced 144.6 million cubic metres, and British Columbia 60.8 million cubic metres of wood. Nearly two-thirds of the B.C. production came from the Interior (Statistics Canada 1983).

Mechanized felling is common in the Interior. Handfalling is restricted to larger trees and where ground conditions are such that mechanical, mobile fellers cannot operate. Industry "best guess" estimates place 50% to 75% of the Interior harvest as being accessible to mechanical felling. This translates to between 19 and 28 million cubic metres per year.

Mechanical Tree Shears

Mechanical tree shearing was introduced to the B.C. Interior around 1966 (McIntosh and McLauchlan 1974). The earliest machines were single-blade, hydraulically-actuated shears, commonly called "snippers", mounted on bulldozers or front-end loaders. Within five years, double-blade feller-buncher heads, mounted on excavator carriers, were also common.

Wood damage was of concern virtually from the introduction of mechanical shears. Various studies were undertaken between 1967 and 1976 by McIntosh and McLauchlan as well as others from the Western Forest Products Laboratory. Some studies were done on felled trees, but others were done in sawmills. The sawmill studies showed volume losses ranging from 0.6% to 7.3% of lumber out-turn per tree.

Private forest companies had also been conducting their own sawmill evaluations. By the mid-1970's, industry had accepted that these damage levels would likely be in the 2.5% to 4% range. This volume was not lost, but was downgraded from higher-value lumber to lower-value chips.

In the early 1970's, the Dika chainsaw head and the auger were introduced to the northern Interior to reduce the problems. Between 1975 and 1977 several companies were experimenting with Swedish chainsaw-equipped felling heads. As well, FERIC was working with Northwood Pulp and Timber Ltd. of Prince George, B.C., to develop a boom-mounted 91 cm capacity chainsaw feller-director head.

Interior Felling Study Group

By 1978 there were enough makes of non-shearing heads that northern Interior companies formed the Interior Felling Study Group. The Group's objective was to generate information on these new products. They commissioned Dr. P.L. Cottell to survey the 1978 status of non-shear felling in B.C. and recommend a direction the Group could follow. Cottell (1978) estimated that over $8 million annually may be being lost to the forest industry in just one of the five Interior Forest Regions, because of shearing damage. His recommendation was that FERIC be engaged to evaluate non-shear felling machinery on a uniform and consistent basis.

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[1]Paper presented at the COFE/IUFRO - 1984. Orono, Maine, USA, 12-14 August.
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INTRODUCING NON-SHEAR FELLING

Cottell's report identified the machines listed in Table 1. FERIC provided butt-damage measurements, an engineering evaluation and production information on several of the feller-bunchers on Cottell's list. Studies were conducted in late 1978 and early 1979. Two interim reports were provided to the Study Group, followed by an industry-wide publication (McMorland 1980).

These studies were the first widespread look at non-shear felling machinery, both in British Columbia and Canada. They succeeded in focusing attention on the wood-damage levels and performance of mechanized felling equipment, and led directly to two results:

a) the development of a new technique for determining volumetric damage levels caused by felling. The procedure uses measurements made in the woods, and not in sawmills;

b) the large-scale stimulation of inventors and manufacturers to develop new, productive and reliable products.

Wood-Damage Measurement

The basic reason for using a non-shear device is to reduce or eliminate the butt-splitting or shatter caused by shears. A prerequisite, then, is a method of assessing wood damage that is cheap, accurate, repeatable, universal, and preferably made at the felling site. Both woods measurements and sawmill tests had been used in the past to quantify damage levels.

Table 1.--Non-shear felling machinery available for use in British Columbia in late 1977 and early 1978.

Felling Unit	Quantity
Feller Bunchers	
Albright	2
Dika	2
Drott auger	1
Kockums 880 Tree King	2
Osa 670	1
Feller Directors	
Dika	7
Northwood/FERIC	1
	16
Not operational	
Morfee buncher, QM buncher, Albright director	

Woods Measurements

Two types of woods measurements have been utilized. Both involved slicing discs from tree butts and examining the discs for damage. Under one method, a damage index was determined for each tree by summing the lengths of visible surface fracture on each disc, and then totalling for all "damaged" discs from each tree.

The second method simply involved cutting discs from felled trees until damage had been eliminated. The total length trimmed was the measure of damage. A minor modification of this technique was used by FERIC for our initial measurements of non-shear felling units. Only those cracks which extended into the largest square cant obtainable from the log-section diameter were considered as damage (fig. 1). Comparisons were based on total splitting length and the number of trees with splits inside the maximum cant.

All methods were valid and could identify whether shatter existed or not, but did not provide estimates of how much volume was affected by splitting.

Sawmill Studies

A sawmill test is probably the most accurate method of determining (for a given mill and set of other conditions) the volume of lumber lost because of felling damage. Sawmill tests have drawbacks however: they require tracing of individual logs from woods to mill; they reflect any additional damage done to the logs in subsequent phases, particularly in loading/unloading; they take time and are labour intensive, hence expensive; they involve the cooperation of many people; and comparisons between mill studies are often difficult to make because the results depend on the sizes of board cut, mill sawing policies, experience of mill workers, type of milling equipment, lumber grading rules, and length of drying time in a kiln. Because of these difficulties, sawmill studies were not considered as the best measurement tool for determining damage levels on a large number of widely separated felling units.

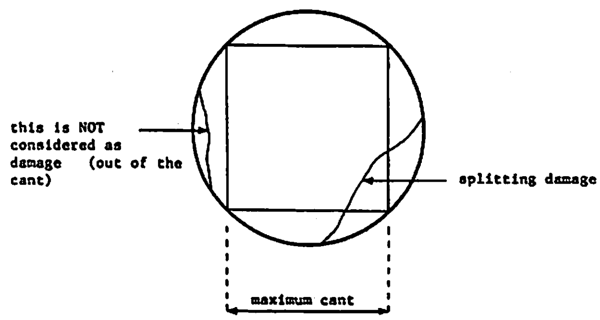

Figure 1.--Splitting damage as measured by the square-cant method.

The "Bicycle-Wheel Method"

FERIC developed this technique to give an idea of volume loss from measurements taken at the felling site or at a woods landing (Guimier and McMorland 1981). The method relates splitting length to the cross-sectional area that has been split or shattered (fig. 2). A 2-inch by 2-inch (5 cm X 5 cm) grid is placed over the discs to be examined. The ratio of squares "with" splits to "total" square count gives the percent of the disc affected by shatter.

The grid is used at 60 cm length intervals from the butt, corresponding closely to the 2-ft. multiples that Canadian sawmills use to provide standard lumber lengths. The volume is calculated for each 60 cm section that shows splitting on the first disc of the section. The volume loss is obtained by multiplying the section volume times the percentage of the disc that was damaged. The "damaged" volumes are summed to obtain total damage to the tree. For a full survey, the volume loss percent is the sum of all damaged volumes from all trees, divided by the total volume of all trees in the sample.

This assumes that all lumber would be in the form of 2-inch by 2-inch boards. Since most mills cut a variety of dimension lumber, sawmillers would have difficulty relating this information to their conditions. As the board size increases, there is a greater chance of a split affecting an individual board (fig. 3), hence the percentage of wood loss is higher.

We used a simulation to develop a procedure for adjusting the 2 X 2 results to other lumber sizes. We have since standardized our results presentations to use an "average" lumber size of 2 X 6. Using the example in figure 2, the volume loss percent for that tree was calculated

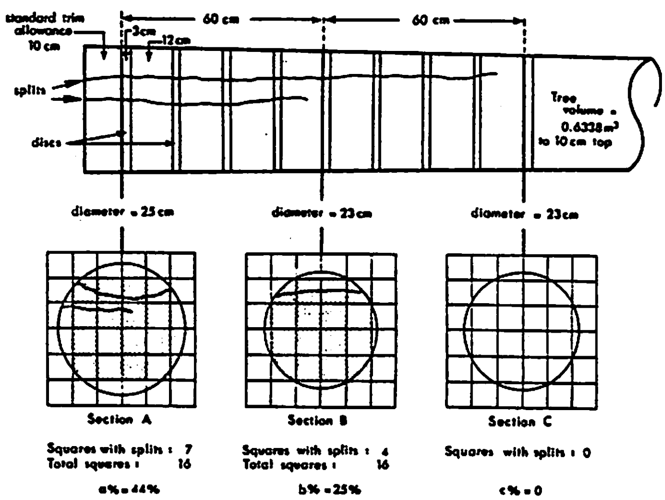

Figure 2.--How to measure butt damage using the bicycle-wheel method. The technique was so named because the first grid developed consisted of a rim from a bicycle wheel strung like a tennis racket.

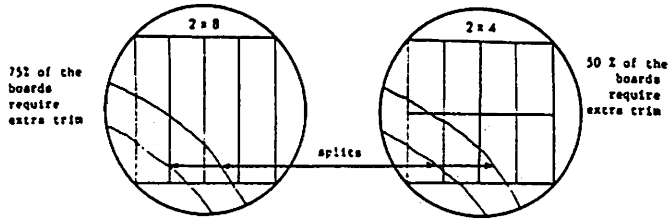

Figure 3.--Influence of the size of board cut on the percentage of wood loss.

to be 2.9% based on a 2 X 2 grid. Converting to a 2 X 6 size, the volume loss becomes 4.4%.

This measurement technique provides an inexpensive and reliable way to compare alternatives and several Canadian and U.S. forest companies have indicated they used it.

Increased Machine Alternatives for Industry

The Interior Felling Study Group had fulfilled their desired function by late 1979. They had generated information and much discussion about non-shear felling. The auger, Dika buncher and Dika director gained further acceptance in B.C. between 1979 and the spring of 1981. No new makes of non-shear heads were introduced to the B.C. market during that period, but much planning and development work had gone on, both in and outside the Province.

Development in B.C.: 1979-1981

The Anda chainsaw head (61 cm capacity) was introduced in the spring of 1981. This was the first made-in-B.C., narrow-kerf, chainsaw feller-buncher head. It was designed, fabricated and marketed by a small independent Prince George businessman. In the summer of that year, Kockums Industries introduced the first Kockums chainsaw head (55 cm capacity) to be made available without having to purchase a Kockums carrier.

Development Outside B.C.: 1979-1981

In Eastern Canada, FERIC had monitored limited experimentation in 1978 with a Jonsereds chainsaw head and an auger. However, the eastern industry was less interested in non-shear felling for two reasons: first, because they were primarily pulpwood producers; and second, shears were less expensive and more productive than non-shears in the smallwood that predominates.

FERIC's Eastern Division had become involved with Prince Albert Pulpwood Ltd. in Saskatchewan in 1977, who were experimenting with high-speed continuous felling using a large, circular saw to fell 10-18 cm. d.b.h. trees. Our Eastern Division was also aware of Western interest in wood-damage levels, and in 1979, a test was conducted on the machine to determine the extent of damage. Very little was found, which led to a FERIC proposal that this concept be dedesigned for a feller-buncher application (Folkema and Mellgren 1982). Koehring Canada Ltd. and Harricana Metal Inc. were approached, and both undertook the fabrication of their own version of a circular saw feller-buncher head. Koehring introduced a pre-production model in Eastern Canada in mid-1981, with the first B.C. head arriving later that year. Harricana developed several prototypes in 1980-1981, with a preproduction model being tested in Eastern Canada in January 1982. Harricana's first B.C. head arrived in June of that year.

Survey of Non-Shear Bunchers

By April of 1982, augers and several makes of chainsaws were in use in B.C. The introduction of large-blade circular saws had also aroused interest. There were verbal reports of a variety of other makes about to enter the market. FERIC was asked to help clarify this picture by determining the current status of non-shear equipment in B.C., particularly the feller-buncher types.

FERIC spent the next several months tracking down machines and interviewing the owners, distributors and some manufacturers. A special, restricted report was prepared (McMorland 1982) for the use of FERIC member companies and the study cooperators. The report differed from most FERIC reports in that it was a snapshot view of the state-of-the-art. It was also subjective and contained opinions of users, dealers and manufacturers.

FERIC identified 13 existing or planned non-shear feller-buncher makes, representing 105 felling units, that were expected to be operational in B.C. by the end of 1982 (table 2). These numbers represented a three-fold increase in types and a 13-fold increase in machines in five years.

Three of the makes (Morfee, Yorston and Dag bunchers) never attained operational acceptance, mostly because of problems in the development phase. Even so, the population of buncher heads was impressive. The list did not include about a dozen director-style units.

The introduction of non-shear felling equipment was not without problems. FERIC's studies and surveys had highlighted four major factors.

1) There were many products to choose from, and little industry experience with design features important for a non-shear head.

2) Users generally found non-shear equipment to be 15% to 30% less productive than a comparable-sized shear.

Table 2.--Non-shear feller bunchers expected to be operational by end of 1982.

	Operational	For Sale	Under Assembly
Production-Level Design			
Auger	21	10	-
Dika buncher	12	1	-
Kockums chainsaw head	15	12	20
Kockums 880 Tree King	2	-	-
Osa 670	2	1	-
Subtotal:	52	24	20
Pre-production or Prototype			
Koehring circular saw	1	-	-
Anda chainsaw	2	-	-
Harricana circular saw	-	-	1
Denis 2-blade circular saw	-	-	1
Spencer chainsaw	1	-	-
Morfee chainsaw	-	1	-
Yorston ("QM buncher")	-	-	1
Dag chainsaw	-	-	1
Subtotal:	4	1	4

Grand totals: number of makes 13
number of units 105

3) New cost centres were encountered. Examples included new operating costs of cutter and sharpening; modification or frequent repair and redesign; and carrier repair where the suspected cause was related to the head.

4) Some products appeared on the market accompanied by confusion or uncertainty. In some cases, too many dealers were involved, resulting in few dealers becoming knowledgeable about any one product. In others, users were inexperienced in trouble shooting and repairing the more complicated electrical and hydraulic systems of many non-shear heads, particularly when manuals were not provided. In still other cases, mainly with the circular saws, there was uncertainty whether or not existing carrier hydraulic systems would permit proper and full utilization of the head's capabilities.

Butt-Damage Studies

By the end of 1982 several Interior forest products companies had converted from shear heads to non-shears. There were indications that other companies would follow in 1983. There was, however, a lack of information about the wood-damage levels caused by the newer designs introduced the past summer and fall. In January and February of 1983, FERIC undertook an examination of wood-damage levels using the grid technique from The Bicycle Wheel Method. A mechanical engineer from FERIC also observed the heads in operation, in order to comment on factors influencing butt damage. A report was prepared and issued as a supplement to the Survey report (Guimier 1983). During the course of 1983, several additional makes of felling heads appeared--the Lokomo Cone Saw and the Boreal twin-blade circular saw, as feller bunchers; and as directors, the Hultdins and QM Saw (chainsaw types) and the circular-saw style RotoSaw. The Lokomo and Boreal have not yet been available in B.C. winter conditions.

FERIC conducted further wood-damage studies in January and February of 1984. Table 3 contains the results of both sets of studies. The felling systems include a handfaller and two types of shear heads for comparison. The systems are ranked in increasing order of percent volume loss.

The handfaller shows the least damage while the shears show the most. The results presented in table 3 should not be taken as an absolute characterization of the system's performance in all conditions. The data represent damage observed for a system with a given operator in a very specific set of stand, terrain, weather and other conditions.

Factors Influencing Butt Damage

In addition to collecting butt-damage data, FERIC carried out an engineering investigation of most of the systems to determine the causes of butt damage and how they can be avoided. Three major factors affect the damage results:

- stand characteristics;
- operator; and
- machine.

Each one will have an effect on the amount of butt damage. After discussing these factors, we will elaborate on the details of machine design since it represents the main potential for systematic butt-damage reduction.

Stand Characteristics.--Tree size is a major factor influencing wood loss from shatter. Usually, small trees result in a larger percent volume loss than large trees for two reasons. First, they are bent more easily by feller-bunchers

Table 3.-- Butt damage summary--ascending order of % of volume loss

Rank	Felling System	Type	% Volume Loss (2 X 6 Basis)	No. of Trees Measured	Trees with Damage No.	%	Av. Butt Diameter cm
1	Handfaller	chainsa..	0.05	57	2	4	35.3
2	Spencer	chainsaw-buncher	0.12	44	7	16	36.1
3	Koehring 2	circ. saw-buncher	0.15	64	5	8	33.2
4	Harricana 2	circ. saw-buncher	0.17	68	9	13	28.0
5	Harricana 1	circ. saw-buncher	0.20	57	9	16	31.5
6	Dag	chainsaw-director	0.41	50	17	34	30.4
7	Dika Buncher	chainsaw-buncher	0.45	54	22	41	34.6
8	Osa	chainsaw-buncher	0.49	56	16	29	27.1
9	Denis 2	circ. saw-buncher	0.56	21	6	29	31.7
10	Dika Director	chainsaw-director	0.62	65	32	49	36.1
11	Kockums 2	chainsaw-buncher	0.63	58	38	66	31.7
12	Hultdins	chainsaw-director	0.67	53	30	57	37.1
13	Auger	auger-buncher	0.73	56	16	29	25.5
14	Koehring 1	circ. saw-buncher	0.83	64	17	27	27.7
15	Anda	chainsaw-buncher	0.88	75	44	59	34.5
16	Kockums 1	chainsaw-buncher	0.92	26	11	42	31.0
17	Denis 1	circ. saw-buncher	1.28	77	31	40	25.8
18	RotoSaw Director	circ. saw-director	1.30	64	49	77	31.0
19	QM Saw Director	chainsaw-director	1.43	64	22	34	25.2
20	Harricana 3	circ. saw-buncher	1.46	50	22	44	31.1
21	NW/FERIC FD	chainsaw-director	1.86	39	30	77	40.7
22	Forano 1 (shear)	cupped, double blade	3.34	64	57	89	25.0
23	Forano 2 (shear)	cupped, double blade	3.36	55	51	93	35.1
24	QM Shear 1	straight, single blade	3.36	38	38	100	41.1
25	QM Shear 2	straight, single blade	4.54	56	55	98	30.3

and bending causes higher stresses to be applied to the uncut wood. Secondly, percent volume loss is a function of the percentage of the cross section that is damaged by cracks. A crack at the edge of a small log affects a larger proportion of the area than the same crack would on a larger log.

Tree species and frost depth in the trees also influence damage levels. Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) showed the least loss. Lodgepole pine (*Pinus contorta* Dougl.) and Engelmann spruce (*Picea engelmannii* Perry) showed comparable damage, while balsam (*Abies balsamea* (L.) Mill.) appeared to show slightly more damage than pine or spruce. Colder temperatures have been found to increase wood-damage levels (Johnston and St. Laurent). Only one of FERIC's winter studies was conducted in very cold weather. Kockums 1 was measured in the winter of 1981-82, which was quite severe. The winters of 1982-83 and 1983-84 were both mild, with temperatures rarely below -10 degrees Celsius. Kockums 1 showed about 45% more damage than a similar machine (Kockums 2) evaluated in February 1983 in the same area. Differences in the amount of frozen wood help explain the variation.

Leaning trees, odd-shaped stumps, large and low branches, trees growing side by side, rough and steep terrain, deep snow and any other stand characteristics that increase felling difficulties will all contribute to damage.

Machine Operator.--Operators' techniques affect butt damage. Most of the operators appeared to be proficient, but we noted some techniques that led to increased damage. Many of these were developed to overcome a machine problem. For example, many operators had to bend the tree in order to keep the kerf open and prevent the cutter from binding. Also, the sidetilt feature was not always used because operators felt they were under pressure to produce.

Production versus quality will require compromise but the designer must strive to build a machine which will minimize damage and maximize production without requiring extra skill from its operator.

Machine Design Features.--The type and arrangement of the felling head components will determine how much damage is created. The machine design is the most important factor to investigate when studying butt damage because it is the factor that can be most easily controlled and improved.

In order to organize our analysis of the felling machine's design features, we divided the felling cycle into the following five work elements. Each element can contribute to butt damage:

1) positioning head on tree;
2) cutting;
3) kerf opening;
4) supporting the tree weight after cutting; and
5) holding the tree (feller buncher) or pushing/directing the tree (feller director) while it is being severed.

Butt damage can occur during any of these elements if they are not properly executed. If any element causes the tree to be stressed (fig. 4) during the cutting phase, damage is unavoidable.

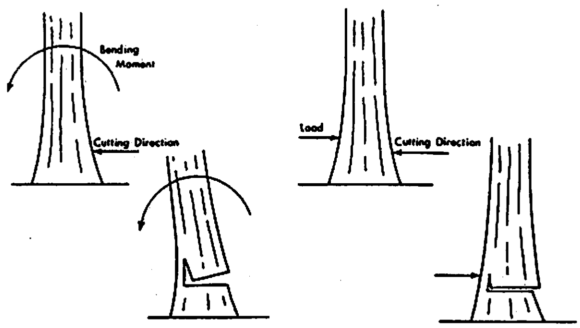

Figure 4.--Bending moment and/or loads perpendicular to the tree during the cutting phase result in butt damage.

Positioning the head should not bend or deflect the tree. For all the feller-director machines, positioning only involves placing the head around the tree base. For feller-bunchers that grasp the tree before cutting, it is critical that the head be aligned to the tree. If head positioning is not perfect, bending and shear stresses will be applied when the grab arms are closed and damage will result. Unfortunately, aligning the head takes time and reduces production. Positioning is less critical for the Spencer, Koehring and Harricana heads because no attempt is made to grab the tree before cutting starts.

Four types of cutting devices were used to fell the trees measured in these studies: chainsaws, circular saws, auger, and shears. Most of the damage created by the shears can be attributed to the cutting device (the knife). None of the non-shear devices appears to be superior to the others for cutting action alone, although the Dika's coarse chain occasionally tends to rip chunks out of small trees. However, the way the cutter is fed into the tree determines the shape and location of holding wood, and therefore the direction most sensitive to splitting. Regardless of the pivot point of the cutter or the cutter travel direction, barberchaining can be caused by applying a force IN THE DIRECTION OF CUTTER TRAVEL. This force will create a failure stress in a plane at right angles to the cutter travel direction.

The requirement for keeping the kerf open to prevent the cutter from binding is a major source of damage. Some heads, like the auger and large circular saws, are less susceptible to binding, because they can either cut themselves free or they have a sturdy follow-plate on which the tree butt will rest. A follow-up wedge is used on some chainsaw heads, but the wedge also gets pinched if the kerf is not opened by other means. Most heads require operator input to open the kerf, and depending on the cutter travel direction on a particular head, different actions are necessary. Some heads must be tilted sideways, while others must be tilted towards or away from the machine. Unfortunately, keeping the kerf open usually requires applying loads to the tree in the direction most sensitive to splitting. Operators can have difficulty in judging how much push is required, and can end up over-pushing the tree.

Several solutions to this problem are possible.

1) Use cutters that are insensitive to binding.

2) Use a combination cutter and sturdy, tapered wedge that eliminates the need for operator input.

3) Encircle the tree slightly above the cut line and apply enough clamping force to prevent the butt from splitting.

4) Apply the moment necessary to open the kerf in such a way that the barberchairing takes place in the stump rather than the butt log. Figure 5 shows a simple example of how a barberchair-type of split can be created to the left or right of a notched beam. The same general idea could be used to try and split a tree stump instead of the butt log.

Most heads must also support the tree weight after it has been cut. Many of them have support plates or bars strong enough to hold the tree, but other machines (Kockums, Spencer, Anda, Denis, Osa) have to rely mostly or entirely on the grab arms. This need to grab the tree firmly results in stresses, and can lead to increased damage.

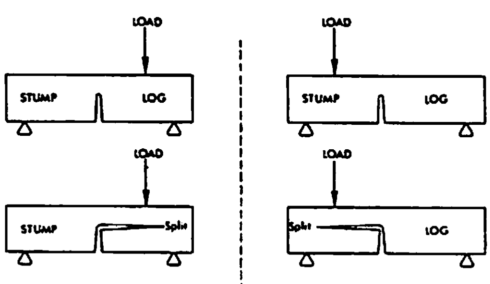

Figure 5.--The direction of splitting depends on how the load is applied to open the kerf.

Holding the tree (or pushing in the case of some feller-directors) can be done before or after the tree is cut. The five top ranked (i.e. least damaging) studies on mechanized equipment were all conducted on systems that do not grab the tree until cutting has been completed. Damage levels could be reduced by postponing grab-arm closure until the tree has been cut but, unfortunately, most machines still require that grab arms be used to keep the kerf open or to support the tree weight.

CONCLUSIONS

Non-shear felling machinery has been introduced to Interior British Columbia on a large scale. There are many makes and models of felling heads, but all appear to reduce wood-damage levels from that of shears. Some products are approaching the very low levels of handfalling.

Stand conditions, machine operator and machine design features all influence wood-damage levels. However, it is machine design which represents the main potential for systematic butt-damage reduction. For a machine which will minimize butt damage:

- do not use shears;
- leave the tree free during the cutting process;
- design the cutter so it is less sensitive to binding;
- design the machine so that the stump will tend to split (not the log) when bending is applied to open the kerf; and
- eliminate any opportunity for the operator to apply uncontrolled stress to the tree during cutting.

LITERATURE CITED

Cottell, P.L. 1978. Tree-felling machines: a review of alternatives to the shear. Contract report to the Interior Felling Study Group, Prince George, B.C. Published by FERIC, Vancouver, B.C. 59 p. 5 app.

Environment Canada, Canadian Forestry Service. 1984. Selected forestry statistics - Canada. Information Report E-X-32. Hull, Quebec.

Folkema, M.P. and P.G. Mellgren. 1982. Using circular saw felling heads to reduce butt damage and increase productivity. FERIC Technical Note No. TN-58. 22 p. Pointe Claire, Quebec.

Guimier, D.Y. 1983. Butt-damage levels of non-shear felling heads in British Columbia. FERIC Special Report No. SR-19A. 22 p. Vancouver, B.C.

Guimier, D.Y. and B. McMorland. 1981. The bicycle-wheel method: a procedure to evaluate butt damage in the woods. FERIC Technical Note No. TN-52. 17 p. Vancouver, B.C.

Johnston, J.S. and A. St. Laurent. 1971. Cross-cut shearing of frozen trees. Pulp and Paper Magazine of Canada 72(5): 97.

McIntosh, J.A. and T.A. McLauchlan. 1974. Damage reduced in single-blade tree shear tests. British Columbia Lumberman, June 1974. Vancouver, B.C.

McMorland, B. 1980. Non-shearing felling heads. FERIC Technical Note No. TN-34. 48 p. Vancouver, B.C.

McMorland, B. 1982. Survey of non-shear feller-buncher heads in British Columbia. FERIC Special Report No. SR-19. 71 p. Vancouver, B.C.

Statistics Canada. 1983. Canadian forestry statistics - 1981. Catalogue 25-202. Minister of Supply and Services Canada. Ottawa, Ontario.

PRODUCTIVITY OF THE VALMET 940 GP GRAPPLE PROCESSOR IN SOUTHERN PINE PLANTATION THINNING[1]

W. Dale Greene
Bobby L. Lanford
Bryce J. Stokes [2]

Abstract -- A Valmet 940[3] grapple processor was added to a mechanized thinning crew, replacing three sawhands and improving the quality of wood produced. Addition of the processor slightly improved the productivity of the forwarders and provided a better method for disposal of the remaining slash after delimbing and bucking. Such processors appear promising for replacing dangerous and less productive manual delimbing and bucking operations in the South.

INTRODUCTION

In the southeastern USA, there are presently 9 million hectares of pine plantations. This is equivalent to the entire commercial forest land area of the states of Maine and New Hampshire. At present 350,000 ha are annually available for thinning with this area expected to reach 1 million ha by the end of the 1980's.

The predominant thinning methods in the South remain highly labor-intensive. These operations are plaqued by hazardous working conditions, limited woods access, wet or steep ground conditions, low man-day productivity, and poor worker motivation. As a result, the supply of wood from such operations is highly unpredictable and weather sensitive. To offset this situation, many logging contractors and forest product firms have begun using more mechanized operations which are less sensitive to the above problems. In Alabama, for instance, a major forest products firm started a mechanized thinning crew three years ago. This operation has not only provided silviculturally acceptable thinning but also economical wood to the firm's paper mill. The operation uses small feller-bunchers and forwarders. Shortwood is produced in order to attain maximum legal highway loads on haul trucks and minimize residual stand damage while meeting mill size requirements.

The only job task which was not mechanized originally on this crew was the delimbing and bucking of bunched trees left by the feller-buncher. Large bunches (2.5 m^3) were built in order to maximize forwarder productivity. Even though the chainsaw operators were highly trained and motivated, their work quality was less than that needed to meet highway and mill standards. Vines, limbs, and other trash remained in piles after bucking as workers sacrificed quality in an attempt to achieve high productivity. During the hottest part of the summer, worker productivity was reduced due to extreme heat and humidity. To overcome these problems, a grapple processor -- the Valmet 940 GP -- was added to the operation, replacing three chainsaw operators.

PROCESSOR DESCRIPTION

The Valmet 940 GP (Figure 1) is a Finnish multi-stem grapple processor. Although designed for Scandanavian and European carriers, most North American front-end loaders can be adapted to serve as the carrier. The processor reported here was attached to a Cranab boom mounted on a Timberjack 385 skidder.

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[1] Paper presented at the conference COFE/IUFRO - 1984, Orono, Maine, USA, 12-14 August.

[2] W. Dale Greene is Graduate Research Assistant and Bobby L. Lanford is Associate Professor, Department of Forestry, Alabama Agricultural Experiment Station, Auburn University, Alabama, USA. Bryce J. Stokes is Research Engineer, Southern Forest Experiment Station, USDA, Auburn, Alabama, USA.

[3] Mention of trade names is for the reader's convenience and does not constitute an endorsement by Auburn University or the USDA Forest Service.

Figure 1.--The Valmet 940 GP grapple processor.

The head uses two feed rollers to pull trees through the grapple arms. Three delimbing knives mounted on one end of the grapple delimb trees as they are fed through the head. The stem is automatically bucked to preprogrammed lengths by a measuring wheel inside the processor arms and a hydraulically powered chainsaw mounted on the end opposite the delimbing knives. The processor can delimb trees up to 42 cm in diameter and easily handles multiple stems and poorly formed trees. Specifications for the Valmet 940 are found in Table 1.

Table 1.--Mechanical specifications of the Valmet 940 grapple processor.[1/]

Item Description	Specification
Feeding --	
speed	0-4 m/sec.
force	20 kN
Hydraulics --	
pump requirement	190 l/min @ 33 r/s
working pressure	26 MPa
Mass --	670 kg
Power requirement --	82 kw

[1/] Based on manufacturer's literature.

STUDY DESCRIPTION

Three weeks after its addition to the thinning operation, a time study of the processor was conducted for two working days. The processor operator had operated the machine for several months prior to its addition to the thinning operation. The stand being thinned was a 12-year old loblolly pine (P. taeda L.) plantation in the coastal plain of Alabama. Trees averaged 18 cm in diameter at breast height (DBH) and 15 m in total height. Stocking before thinning averaged 1660 trees per ha. Thinning removed an average of 959 trees per ha, leaving a residual stand of 701 trees per ha.

A feller-buncher built large bunches containing an average of 16 trees or 2.5 m^3 of wood. Distance between bunches ranged from 4 to 18 m and averaged 8 m. The processor delimbed and bucked trees into 2.3 m lengths up to a 7.5 cm top outside bark. All bunches were located adjacent to an access corridor created by the removal of every 11th row of the stand. Bunches were oriented perpendicular to the direction of the row. Productive work elements of the processor consisted of (1) move to bunch, (2) swing to bunch, (3) swing to pile, and (4) process trees. These work elements were combined and analysed as two composite segments -- (1) move to bunch and (2) process bunch. "Process bunch" included the individual swing to bunch, swing to pile, and process trees elements for all trees in the bunch. For our analysis, both composite elements were analyzed on a time per tree basis. This allows a quick comparison of processor productivity on different stands based upon available cruise information.

PRODUCTIVITY AND COSTS

Move time between bunches averaged 0.02 productive minutes per tree. Move time per tree was affected by the distance traveled and the number of trees in the bunch (Figure 2). Distance between bunches was a function of corridor spacing and the number of trees removed per ha. As the distance between corridors decreased or as the thinning intensity was reduced, the distance between bunches was increased.

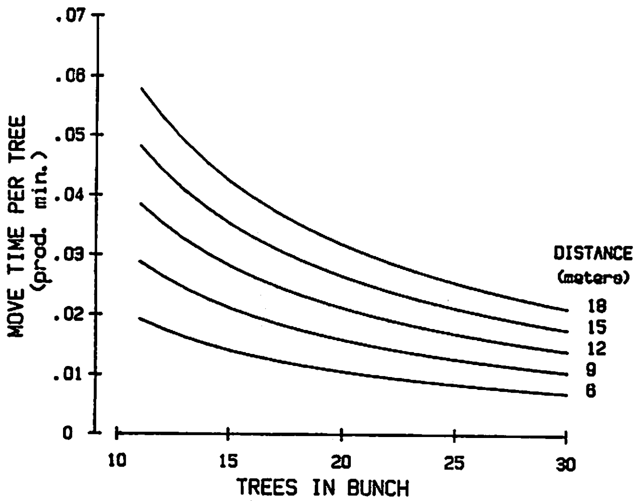


Figure 2.--Move time per tree for various distances between bunches as a function of number of trees in the bunch.

Processing time per tree averaged 0.40 productive minutes per tree. Processing time was affected only by the size of the tree. For instance, it took 0.24 productive minutes to process a 12 cm tree while taking 0.61 productive minutes to process a 20 cm tree. For each 5 cm increase in diameter, it took an additional 0.23 productive minutes to process. A direct linear relationship existed between processing time and DBH (Figure 3).

Total productive time per tree was obtained by adding move and processing times. Total time per tree was affected only by DBH since processing accounted for 95 percent of the total time per tree. Total time for a 12 cm tree was 0.25 productive minutes while for a 20 cm tree it was 0.64 productive minutes. However when tree volume was considered, the production rate (m/PMH) was much higher for larger trees (Figure 4).

Cost for the processor was estimated with a machine rate. Ownership costs were estimated at $25.84 per PMH and operating costs (including

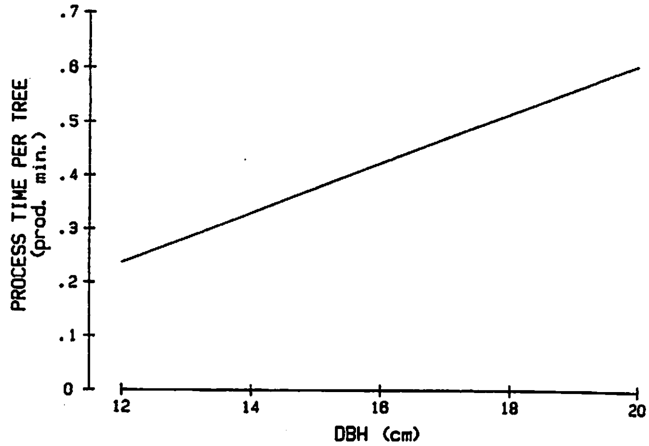


Figure 3.--Processing time per tree as a function of DBH.

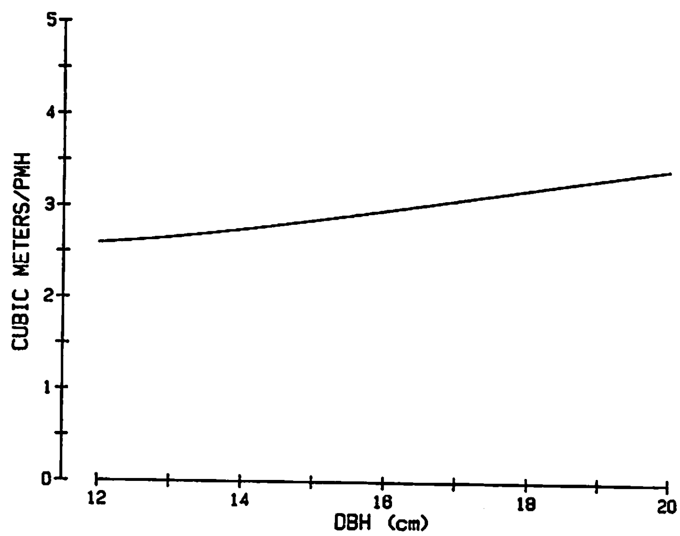


Figure 4.--Production rate as a function of DBH.

labor) at $34.41 per PMH for a total cost of $60.25 per PMH. Production averaged 18.7 m^3 per PMH during our study, resulting in an estimated cost of $3.22 per m^3. By comparison, chainsaw delimbing and bucking cost for the same stand was estimated at $2.83 per m^3. Due to the high variability of logging costs, these small differences may not be significantly different. Also, the processor offers other advantages which affect the overall cost of the thinning system. These advantages include:

(1) Safety. Chainsaws have been eliminated from the system and all workers are off the ground and mounted on machines.

(2) More silviculturally acceptable residual stand. This is due to:

(a) logging slash being deposited in the access corridor where subsequent machine travel breaks it down. Prior to the addition of the processor, such slash was left in piles which posed potential hazards from insect infestations and hotspots during prescribed or wild fires.

(b) feller-buncher piles being built adjacent but outside the access corridor. This allowed the use of more narrow corridors and reduced the damage to the residual stand due to machine movement. Since access corridors are narrower, residual trees are more evenly distributed over the site and fewer high potential trees are removed.

(3) Better fiber utilization. Since the processor handled four or fewer trees at a time, the entire merchantable stem of the tree was better utilized. By comparison, with manual delimbing and bucking of such piles, taller trees at the bottom of the pile were often poorly utilized since they could not be seen or properly bucked.

(4) Improved forwarding and hauling productivity. Piles were cleaner and larger. Less trash eliminated the need for trimming prior to the final haul as was the case with the manual approach.

CONCLUSIONS

For many operations, the advantages of mechanized processing will offset the higher per unit costs and capital investment. Such machines are easy for operators to learn to use and remove the dangerous chainsaw from the hands of the operator. While more information is needed on these machines in southern applications, their future appears promising for use in thinnings.

SKIDDERS USING HIGH FLOTATION TIRES[1]

Brent J. Sauder[2]

Abstract.--Equipping a rubber tired skidder with high-floatation (HF) tires increases the area of applicability for ground skidding on the west coast. A skidder equipped with HF tires was monitored while yarding two sites on nothern Vancouver Island and achieved production levels of 57 and 72 m^3/shift; improved productivity levels are anticipated. An analysis of potential environmental impact indicates that the use of a skidder could increase the net present worth of a setting over that achieved when using a cable system by $1,301/ha even when yield loss due to compaction is considered.

INTRODUCTION

Since 1980 FERIC and several tire manufacturers have worked to develop high-flotation (HF) tires for wheeled skidders. These tires are wider and operate at lower inflation pressures than conventional skidder tires (fig. 1). Operational experience with HF tire equipped skidders in eastern Canada (Mellgren and Heidersdorf 1984) has identified several advantages over conventionally tired skidders including:

- increased productivity
- reduced fuel consumption
- reduced ground disturbance
- reduced soil compaction
- improved operator comfort
- improved machine stability.

These results indicated that HF tires had the potential for increasing the coastal forest area suitable for skidder operations.

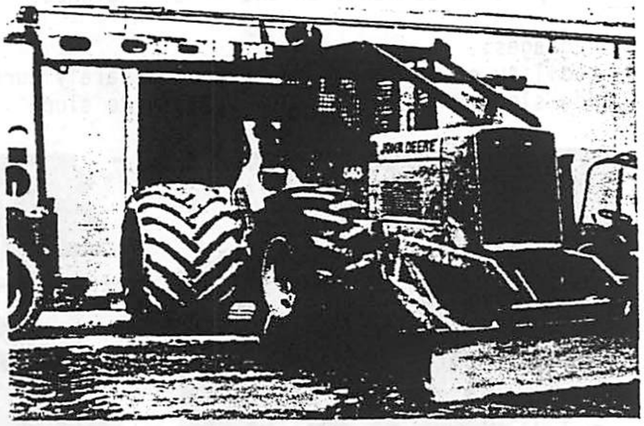


Figure 1.--Conventional 23.1x25 tire (front) inflated at 151 kPa (22 psi); HF 66x43x25 tire (rear) inflated at 83 kPa (12 psi).

This paper presents the performance results for a HF tire equipped John Deere 640 line skidder operating on the east coast of Vancouver Island. The trials are part of a one year study funded by the Canadian Forestry Service, to evaluate the performance of HF tires and the B.C. Ministry of Forests, to determine the site impact.

TRIAL DESCRIPTION

Sites

The HF tired skidder operated at five locations during the one year study. Table 1 describes the conditions at two locations (results for all sites will be presented in the final report to the CFS) both on the east coast of northern Vancouver Island. Site 1 is a low elevation, 40-year-old alder (Alnus rubra Bong.) site which was rehabilitated to conifer; site 2 is a mid elevation, 75-year-old hemlock (Tsuga heterophylla (Raf.) Sarg.) and Amabilis fir (Abies amabilis (Dougl.) Forbes) stand. Site 1 was logged during the winter of 1983-1984; site 2 was logged in the spring of 1984.

Table 1.--Site Descriptions

	Site 1	Site 2
Topography	Flat terraces, one major hill with slopes up to 40%	Undulating terrain, slopes reaching 35%
Timber Type	Red Alder 73% Conifer 27%	Hemlock 77% Amabilis Fir 23%
Stand Volume	150 m^3/ha	753 m^3/ha

[1]Paper presented at the conference COFE/IUFRO - 1984. Orono, Maine, USA, 12-14 August.

[2]Brent J. Sauder is Sr Research Forester, Wood Harvesting Research Division, MacMillan Bloedel Limited, Vancouver, B.C., Canada.

Harvesting Systems

Both settings were felled manually and skidded tree length using a John Deere 640 line skidder (table 2). A portion of site 2 was harvested using the "cut and skid" system with trees felled one turn at a time.

Table 2.--Harvesting System

	Site 1	Site 2
Felling	Manual felling, clear fell	Manual felling, clear fell and "cut and skid"
Skidding	Full tree, limb and top at landing	Full tree, limb and top at landing
Tire Type	Goodyear 66x43x25 Firestone 66x43x24	Firestone 66x43x24

Tires

Tires supplied by Goodyear Canada Ltd. and Firestone Canada Inc. were tested (fig. 2). Both tires were inflated to approximately 83 kPa (12 psi). With the tires installed, the overall width of the machine was approximately 3.6 m (12 feet). The major difference between the tires was in their lug angles; 45° for Goodyear and 23° for Firestone.

RESULTS

For the two sites, mechanical availability exceeded 90% (table 3). Overall, tire problems accounted for only a 1% loss in mechanical availability. Wire rope, mechanical problems and service time contributed to the remaining 8% loss. Machine utilization for site 2 was low due to weather and faller related delays.

Greater productivity for site 2 reflects the larger piece size for that setting (table 4). Considerable time was spent clearing skid trails in site 2. Overall production for these two areas was lower than anticipated, perhaps reflecting the poor weather conditions (heavy rains) during the trial.

Table 4.--Skidding Performance with HF Tires

	Site 1	Site 2
Turns/Shift	16.0	17.0
Pieces/Turn	5.0	3.3
Pieces/Shift	79.2	55.7
Average Piece Size, m^3 net	0.7	1.3
m^3/Shift	57.0	72.4
m^3/PMH	9.8	13.2

DISCUSSION

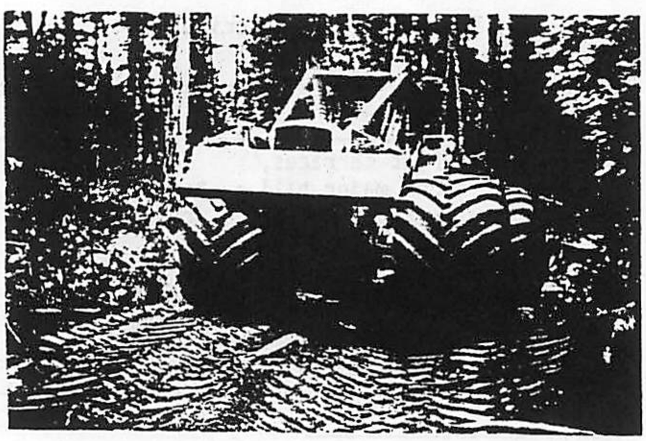
Operational Results

The HF tires have survived a years operation under west coast logging conditions and are a feasible alternative to conventional skidder tires. The trials have demonstrated that a tire width of approximately 1 m (43 inches) is adequate for flotation and does not prevent the skidder from maneuvering between the stumps. Some contractors are considering HF tires of larger diameter to improve machine ground clearance. The Firestone's 23° lug angle appeared to give better traction in slippery conditions than the Goodyear's 45°.

Operator comments on the tires included:

Advantages:

Stability on side slope	- the machine could safely turn around on a 35% side slope



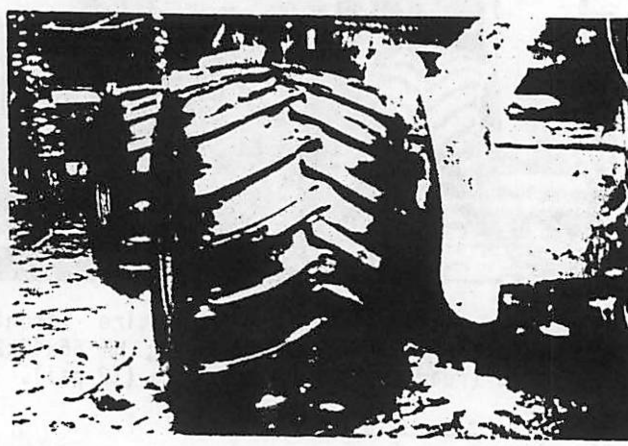


Figure 2.--Goodyear 66x43x25 HF tire (left) - 45° lug angle
Firestone 66x43x26 HF tire (right) - 23° lug angle

Table 3.--Distribution of Scheduled Skidding Time

	No. of Shifts	Machine Hours/Shift Scheduled (SMH)	Productive (PMH)	Delay Hours/Shift Repair Machine	Tires	Service	Nonmechanical	Availability %[1]	Utilization %[1]
Site 1	48	8	5.8	.6	-	.1	1.5	91	73
Site 2	22	8	5.5	.1	.2	.5	1.7	90	69
Weighted Average	70	8	5.7	.4	.1	.2	1.6	91	71

[1]Berard et al 1968

Stability while winching - on steep slopes the larger wheel base gave good footing while winching

Softer ride - on established skid trials and areas relatively free of debris the wide axle beam resulted in a smoother ride

Wet area traction - the machine was able to skid turns through wet areas inaccessible to skidders equipped with conventional tires

Uphill traction - the machine could push with greater force on uphill grades to clear debris and stumps (stumps were left in place wherever possible)

Disadvantages:

Loss of traction - wide tires prevented "spinning out" of tops and debris which would allow the tires to make contact with ground

Extra width - wider track resulted in increased tire contact with stumps causing rougher ride and loss of traction when travelling off skid trails; skid trails had to be picked carefully

Performance on slopes - the climbing ability was hampered (especially in reverse) due to loss of traction associated with the stumps and debris; the machine did, however, operate successfully on slopes up to 35%

Applicability - one HF tired skidder in a fleet of three or four skidders would give a contractor the flexibility to operate in wet and sensitive areas

[3]Weinard, R.H. 1984. Personal correspondence. Northwood Pulp and Timber Ltd., Prince George, B.C.

The contractor who operated the skidder in site 2 suggested the installation of "light chains" to overcome the problem of spinning out on debris and barked stumps. Preclearing of major skid trails at a cost of approximately $3,000/km has been considered as a method of improving skidder production. Experience with skidders in other regions indicates that significant productivity improvements should be expected[3].

The lower inflation pressures and tubeless construction of the HF tires does increase the possibility for air leakage at the tire bead. Beads can be pushed away from the wheel rim if the skidder is run alongside log decks or debris is forced between the tire and rim. Clearing the tire bead area of debris should be considered a normal service activity. Neither the Goodyear or Firestone tires require a "bead lock" type rim; no tire/rim slippage occurred during the trials.

The cost of HF tires and rims is also a consideration. Retrofitting a skidder will cost approximately $19,000; a cost which the operator must balance with increased operating opportunities and performance.

Environmental Impact

As the terrain most conducive to skidder logging is also the most productive coastal forest land, there is a recognized concern for the disturbance levels caused by skidding. Soil compaction, causing reduced forest productivity and increased surface water flow on skid trials, has been identified as an impact of skidder logging (Froehlich 1979, Dickerson 1975). However, one must evaluate these concerns carefully.

Example

Assure that: using a conventional rubber tired skidder to skid a clearcut coastal stand would reduce harvesting cost by $3.50/m^3$ compared to cable yarding systems (Wellburn 1975).

In the worst case, there could be a 40% loss in volume yield (over a rotation) for the trees growing on the 12% of the total logged area compacted by skidding (Sidle and Drlica 1981, Power 1974).

Established skid trails would be reused in subsequent harvesting of the area.

Net revenues are after 50% corporate tax stated in constant 1984 Canadian dollars; discount rate (net of inflation) is 4%, therefore:

Case 1 - Cable Yarding

Year	0	80
Volume Removed, m^3/ha	725	725
Net Revenue, \$/m^3	13.00	13.00

Case 2 - Skidder

Year	0	80
Volume Removed, m^3/ha	725	690
Net Revenue, \$/m^3	14.75	14.75

The net present worth (NPW) for each harvesting alternative is:

Case	NPW \$/ha	
1	9,834	Cable Yarding
2	11,135	Skidder

The skidder operation results in a \$1,301/ha increase in NPW even when a generous yield loss due to compaction is considered.

This example does not take into account the spatial distribution of the crop trees in the stand. Trees could be planted on noncompacted soils, beside the skid trails or between wheel ruts, without disrupting stocking densities. Silvicultural practices such as thinning to waste and spacing would tend to concentrate the growth on trees not impacted by the skid trials. The positive effect of established access "paths" for stand management is also not considered.

Soil erosion due to concentration of water flow is a major concern in a high rainfall area such as the west coast. Scheduling of operations, prelogging location of major skid roads, adequate supervision, operator training and post-logging treatment should minimize erosional problems (FERIC 1976) and still achieve an increase in net present worth.

This example assumes a worst case compaction/volume yield loss. Preliminary analysis of the site impact data for the HF tired skidder indicates that, for the silty soil types studied, 20 passes over a skid trail resulted in a 2% increase in soil bulk density; 100 passes were required to produce a 10% increase. On a setting basis there was no statistically significant difference between before and after logging compaction levels[4].

[4]Rollerson T. 1984. Results of soil compaction caused by HF tired skidder, MacMillan Bloedel Limited, Nanaimo, B.C.

CONCLUSIONS AND RECOMMENDATIONS

The skidder trial has demonstrated that HF tires can stand up to coastal logging conditions and do increase the area of applicability for skidders. Two contractors in northern Vancouver Island are currently using HF tires. There is considerable interest among other contractors who see the HF tired skidders as a possible replacement for crawler type skidders. Labor and management problems such as the setting of crewing levels, company/contractor crews and balancing equipment utilization must be resolved before wide spread, company operated, HF tired skidder usage is realized.

Although the HF tires generate a softer ride, research is still needed to improve the operator comfort. Perhaps even lower tire inflation pressures are possible (55 kPa) to improve traction, operator comfort and reduced mechanical shock loadings.

Environmental concerns cannot be ignored, nor should they be overstated. Efforts must be made to minimize the opportunity for catastrophic site degradation. There should be a "learn as we go" approach, with flexibility on the part of both government and equipment operators. A logging method which has the potential to reduce logging costs demands attention even though it may cause some site impact. Rational choices require careful balancing of current values foregone, against future values protected.

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Seeley Logging Ltd.

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LITERATURE CITED

Berard, J.A., Dibblee, D.H.W. and Horncastle, D.C. 1968. Standard definitions for machine availability and utilization. WSI No. 2428 (B-1), Can Pulp Paper Assoc, , 2 pp. Montreal

Dickerson, B.P. 1975. Steamflows and erosion after tree length skidding on coastal plains soil. Trans Am Soc Agric Eng 18: 867-868, 872.

Forest Engineering Research Institute of Canada. 1976. Handbook for ground skidding and road building in British Columbia. 41 p. FERIC, Vancouver, B.C.

Froehlich, H.A. 1979. The effect of soil compaction by logging and forest productivity. Final report to U.S. Bureau of Land Management for contract 53500-CT4-5(N). Oregon State University, School of Forestry, Corvallis.

Mellgren, P.G., Heidersdorf, E. 1984. The use of high flotation tires for skidding in wet and/or steep terrain. Forest Engineering Research Institute of Canada, TR-57. 48 p. Pointe Claire, Quebec.

Power, W.E. 1974. Effects and observations of soil compaction in the Salem district. USDI, Bureau of Land Management, Tech Note No. 256.

Sidle, R.C., Drlica, D.M. 1981. Soil compaction from logging with low ground pressure skidders in the Oregon coast range. Soil Science Soc of Am J 45(6):1219-1223.

Wellburn, G.V. 1975. Alternative methods for logging steep slopes in Nelson forest district of British Columbia. Forest Management Institute, Info Report FMR-X-76. 72 p. Ottawa.

FORCES AND OBSTACLES IN THE MECHANIZATION OF FOREST OPERATIONS IN SWEDEN

Stig B. Andersson

Abstract.--By making historical descriptions of applied forest technology more reliable information of further development can be obtained. Changes occuring in the world outside the forestry sector are often the driving force behind new technology or conversely the obstacles to alternative lines of development.

INTRODUCTION

There is no simple answer to the question of what it is that gives rise to the development and implementation of new technology in forestry. There are a host of contributory factors and only in exceptional cases can a given development be put down to a particular event, such as a technical innovation.

When considering the introduction of new machinery or equipment, companies usually look at the results of financial analyses, in which estimated costs and revenue are the main determining factor. However, if a wider view is to be taken, other considerations must be weighed, such as variations in energy consumption, the implications for employment and the possible impact on the environment. An even wider view would also have to consider international developments, international trade and the world economy.

ADVANCES IN TECHNOLOGY, 1950-1980

In the early 1950s, cutting work was performed almost entirely using hand tools. Chain saws were few and far between and were confined to felling and bucking in large-diameter stands. In those days chain saws weighed about 20 kg. Limbing and barking respectively were done by axe and spud. However, by the mid-1960s much lighter chain saws had been developed, which could therefore also be used for limbing. At the same time, the laborious job of debarking was taken over by machines at the mill. Better training, a larger percentage of permanent workers employed throughout the year, the application of better working methods and a variety of measures making work simpler - all these also contributed towards increasing efficiency.

Extraction in the early 1950s was carried out largely by horse. During the fifties and sixties, horses were gradually replaced by farm tractors and, later, by special extraction machines. The 1960s, in particular, saw rapid advances in extraction techniques: while the mobility, payload capacity and reliability of machines improved, the forest truck road network was also extended, making it possible for extraction distances to be reduced. The shortwood method (involving processing of the trees at the stump to sawlogs and pulpwood bolts in lengths ranging between 3 and 6 m) was the obvious choice in view of the fact that men and horses were the predominant source of power in the forest. This situation prevailed until the post-war years, when machines made it possible for whole-tree and tree-length systems to be used.

The first purpose-built machines for extraction work came from the Soviet Union and Canada in the late 1950s and were designed for hauling whole trees or tree lengths. Shortly before the advent of Swedish-manufactured machines in the mid-1960s, two Canadian machines, the Beloit Tree Harvester and the VitFeller-Buncher were introduced in Sweden. The former limbed and topped the standing trees before felling them, whereas the latter felled and extracted unprocessed trees.

The early 1960s also saw the introductions of the 'Sund' system which involved felling by chain saw, followed by extraction of the trees to the truck road, where limbing and bucking were carried out by machine. In about 1967, mobile logging machines were taken into operation, one of which was the Logma limber which limbed the felled trees and bunched the stems in piles.

A questionnaire survey conducted in 1967 predicted that the use of whole-tree and tree-length methods would increase widely during the 1970s. There are two main reasons why this did not happen: first, processing at the landing had no historical tradition in Sweden. The problems associated with the handling of the wood and transporting it to and from the landing, together with the accumulation of logging residue that was quite worthless in those days, resulted in the majority of forest enterprises abandoning the whole-tree and tree-length methods. Secondly, rapid development took place in the late 1960s of forwarders and mobile processors, that is, off-road machines which limbed, bucked and bunched the felled trees. Since the processors took over the work previously done by cutters after the trees had been felled, the problem of organizing the workforce was eliminated.

The development of feller-bunchers came as a natural complement to the mobile processor. The integration of these two types of machine into a single machine was achieved in the development of the harvester - a machine capable of performing all the jobs previously done by the cutter, with no change in the wood flow nor movement of any operation out of the stand.

In relation to developments in logging and extraction, the technical advances made in the fields of stand establishment and stand treatment were less outstanding. Even today, the extent of mechanization in such silvicultural activities as cutover clearing, artificial regeneration and cleaning is limited. In contrast, scarification, which, during the 1950s was carried out by hand, nowadays is carried out almost exclusively by machines.

As regards silviculture, planting is the most labour-intensive operation and R&D work aimed at mechanizing it has been in progress in Sweden since 1965. The technical difficulties inherent in the mechanization of planting on normal stony morainic soils have been much greater than was first thought, and those planting machines that have been developed are still in the prototype stage.

A somewhat rhapsodic illustration of the development between 1950 and 1980 is given in Figure 1. The curve, which has been smoothed out to some extent, shows the rise in productivity during the period, expressed in cubic metres (gross volume) of output per man-day, from all logging, silvicultural and other activities.

PRODUCTIVITY BETWEEN 1950 AND 1980

The replacement of the axe and crosscut saw by the chain saw, of the horse by the tractor, of the barking spud by barking machines and of seasonal work by year-round work, and the expansion of the forest truck network - all these contributed to the sharp rise in productivity illustrated in Figure 1. Productivity rose from approximately 1.4 m^3 per man-day in 1950 to 2.3 m^3 in 1960 and 6.3 m^3 in 1970.

The sharpest rise in productivity occurred in the early 1960s, which also proved to be a turning point towards a slower rate of increase. During the 1970s, the productivity curve tended to level out completely. In this context, it should be remembered that this fall in productivity was reflected in most branches of industry at that time, not just in Sweden but in many other countries as well.

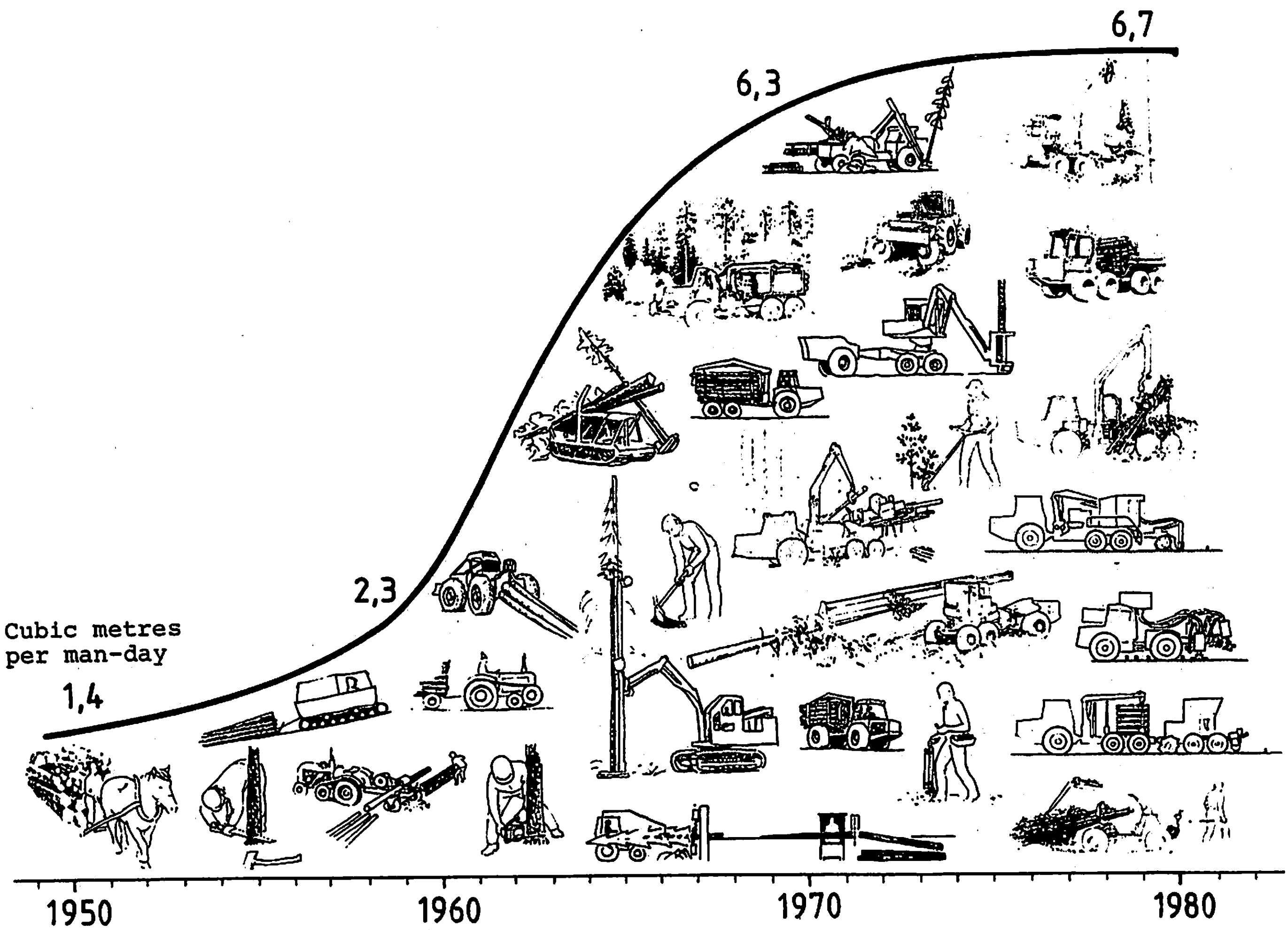

Figure 1

ADVANCES IN FOREST TECHNOLOGY VIS-A-VIS THE OUTSIDE WORLD

A schematic diagram giving a simplified picture of how the outside world influences advances in forest technology is given in Figure 2. Included in the circle in the top right-hand corner of the diagram are international development, trade, industrial conditions, etc. The two-way arrows indicate influences in both directions; for instance, profitability in the forestry sector is influenced by the demand for pulp on the international market but itself influences investment and thus forest technology. In this example, the link between international trade and developments in forest technology in Sweden is fairly direct and readily apparent. However, as the arrows in the diagram show, influence may also be exerted indirectly, such as through national economic policy and public-sector resources. Of course it is difficult to distinguish between cause and effect when the pattern of interrelationships is so complex. To limit the coverage of this paper the various determining factors have been grouped under the following headings:

- General advances in technology
- Profitability trends
- Economic policy
- Governmental controls
- The structure of forest ownership, organizations, etc
- Attitudes and values
- Internationalization

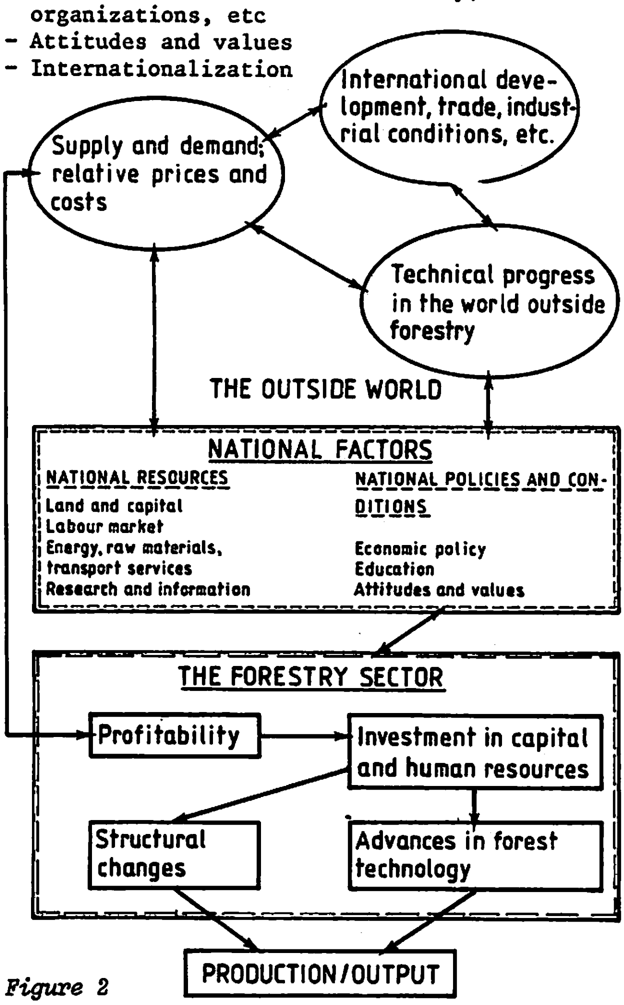

Figure 2

General Advances in Technology

A good example of how general advances in technology can have a major impact on mechanization in forestry was the development of small, lightweight and reliable internal combustion engines, which preceded the breakthrough made by chainsaws during the 1950s. Yet the idea was by no means new.

Another factor having a decisive influence on forest technology was the advances that were made in cross-country vehicles. Although the initial development work was initiated and led by military interests, the techniques have been successfully adopted by the manufacturers of forestry machines. Many of the advances that have been made on forestry machines are associated with advances in hydraulic systems, which will no doubt continue to play an important part in future development work. Advances in electronics, dating back to the 1940s (with the introduction of the transistor) have so far made the greatest inroads in administrative applications. Automation in the process industry followed by the introduction of robots by the manufacturing industry are examples of how electronics have influenced production techniques. With the advances made in micro-electronics (silicon chips) in recent years, new frontiers have been opened up for forest technology, and the new technology is already being used in control systems and automatic bucking equipment on logging machines. So far, these applications have not provided any great incentive to depart from the basic techniques being used at present. But we have still only witnessed the beginning of the breakthrough in microelectronics and all the indications are that a completely new approach to developments in both forest technology and technology in the conversion industry will manifest itself in the not-too-distant future.

Profitability trends

Because of the continual growth in the forest products industry the prices of forest products during the 1950s, 1960s and the early 1970s rose only very slowly. In Sweden, the gap between wages and the price of forest products steadily widened. Thus, to maintain an acceptable level of profitability, the forestry sector was forced to streamline the structure of the industry and mechnize the work. Yet, despite these measures, a declining trend in profitability has been observed since the early 1950s. This trend has probably been the prime force behind the changes and advances that have been made in forest technology.

Investment

Existing investment in forestry machinery and fixed plant at the mills for receiving and handling forest produce constitutes a general disincentive to the introduction of new methods of logging and haulage. The replacement value of existing machinery for logging and extraction in Sweden has been estimated at approximately 4000 million kronor.

The condition of the machinery and equipment varies, from nearly acquired latest-model harvesters to machines bought in the mid-1960s. However, in view of the fairly limited life span of present-day logging machines, the money tied up in them is only likely to impose a short-term restraint on the introduction of new technology. What is likely to be a major disincentive in the long term is the existing investment in fixed plant and equipment for reception, handling and processing of the wood at the mill. In most cases, this type of plant is extremely capital-intensive and has a much longer life-span than that of mobile machines.

Profitability in the long term

The adverse effects of the choice of technique on long-term profitability may sometimes be such that they are deemed to outweigh the short-term gains that can be made. An example of this is the reduction in the productive capacity of the land associated with the removal of branches, needles and tops from some types of soil. Another example is the damage that is done to the residual stand by certain thinning techniques.

Economic policy at national and enterprise level

In large-scale forestry, higher mechanization of logging together with reductions in the annual cut have resulted in a fall in employment in the forestry sector; this depletion in the labour force has made it difficult to complete the necessary silvicultural work. There has been a dramatic rise in the number of workers taking voluntary early retirement and disability pensions, particularly in those areas in which forestry is one of the main providers of jobs. In view of the manifestly adverse effects of this trend, the community at large is now much more sceptical than before about whether continued mechanization and possible automation of logging are a desirable development. The prospects for those made redundant finding alternative work are very limited. The increased difficulty of completing manual silvicultural activities, a situation created by continued mechanization of logging, and also the need for proper jobs in the rural areas, are considerations that have been exerting a steadily increasing influence since the latter half of the seventies.

Governmental controls

Controls that can be applied by the Government, such as legislation, taxation and subsidies, are instruments that can quickly change the conditions under which forest enterprises must operate and R&D be carried out.

The structure of ownership, organizations etc.

Ownership categories and structure, the structural organization and long-established customs in forestry and the forest products industry may act as both incentives and disincentives to the introduction of new techniques.

The economies of scale enjoyed by those operating in the large-scale forestry sector stem from the opportunity to invest in capital-intensive equipment and to make use of specialist staff. In small-scale forestry, investment opportunities are more limited and one person, the woodlot owner operating independently, alone carries out the different activities.

In the past, many new machines and items of equipment developed could also be used by the independent woodlot owners. However, the steady transition to specialized machines during the 1960s and 1970s by the large-scale operators constituted a parting of the ways. To some extent, the small-scale sector was able to avail itself of these developments by cooperating through the forest owner associations, whereas the independent woodlot owners were unable to reap the benefits, apart from those associated with improvements to chainsaws and other items of manual equipment. Clearly, then, the needs of independent woodlot owners provide little incentive to the introduction of new technology into forestry.

Because of the dominance of the pulp and paper industry in Sweden, the wishes expressed by the sawmills and others in the conversion industry have not carried the same weight as they would in other countries. However, fuller realization of the properties peculiar to Swedish timber and the opportunities that the European joinery industries have of utilizing them has now started to forge a new relationship, not only between forestry and the sawmill industry but between the sawmills and the market. It is difficult to predict what implications this change of emphasis will have for future technology, but one logical consequence is that much greater attention will focus on the sawlog section of trees in the future.

Attitudes, values and conservation

The increasing awareness of government and the general public to environmental matters during the 1970s gave rise to public debate about forestry operations and techniques. Of greatest concern were clear-cutting methods and the use of phenoxy acids and DDT, and this concern resulted in the Government introducing regulations in this field.

Another issue that has also been debated to some extent is the use of large machines. Although this has not led to any direct action on the part of the authorities, it does seem to have contributed to the movement towards smaller and less destructive machines. The effect that different forms of forestry acitivity have on the landscape and the ground, combined with the public awareness of such matters can create driving forces of considerable strength. In two projects, one on whole-tree utilization and the other on forest-energy wood, a study has been made of the effects of removing tops and branches from the stand. From the evidence available at present, it seems that the removal of branches, tops and needles in conjuction with final felling is not likely to have any appreciable detrimental effect on the survival and productive capacity of the subsequent plantation, provided the soil is of a normal, mesic type. Conversely, on mesic sites with permeable soils and on dry soils, detrimental effects on subsequent plantations are judged to be much more likely.

The results of limited experiments indicate that the removal of wood from cleanings and of tree sections from early thinnings can give rise to substantial losses in increment. However, this can be offset to some extent by fertilization. The effects of removing tree sections have taken on a topical interest in the current debate on acid rain. If it should be established that the removal of tree sections increases the risk of soils becoming more acidic, this could perhaps constitute the biggest obstacle to the introduction of whole-tree and tree-section methods.

During the 1960s and 1970s, new criteria were introduced to evaluate work. In contrast to the ideals of efficiency and progress of the 1940s and 1950s, higher priority was given to demands that employees should enjoy greater involvement, contact with others and freedom from stress. This reaction against monotonous, highly specialized jobs conducted at a high tempo has led to attempts - particularly in the forest products industry - to develop new forms of work and organization.

From being a manifestly poorly paid group in the 1950s and 1960s forest workers were able to gain wage rises which put them on a par with other industrial workers. Coupled with the opportunity to eliminate physically exerting and hazardous work, this is the main reason for forest workers having such a positive attitude towards rationalization and mechanization. But this development has created widespread redundancies. Moreover, the job of a machine operator involves isolated and monotonous work. Those who have continued work as cutters have had to work on ever-poorer sites and have had to suffer unfair comparisons of their work with that carried out by machines. Consequently, the previously loyal attitude of the workers towards mechanization is now changing to one which is less favourably disposed towards the continued effort to mechanize the work.

Internationalization

Swedish logging machinery is internationally known to be of a very high standard. But machinery has been developed specifically for Swedish conditions in terms of tree diameter, slightly undulating terrain, a divided industrial structure and far-reaching legislation governing working conditions. As mentioned earlier, Swedish logging has revolved almost exclusively around the shortwood system. In this respect, the situation in Sweden differs from developments in most other countries with the exception of Finland.

Another feature of the development in Sweden has been the complex design of machines, which makes heavy demands on operators and service personnel alike. To a degree that is not insignificant, this complexity of design has made for high acquisition costs.

Further, the structure of the manufacturing industry producing these machines is such that the majority of machines have been produced only in very small series. In spite of the high level of technology built into these Swedish machines for short-wood logging, exports to the major wood-producing countries have been very limited. It was a fairly simple matter to adapt earlier Swedish technology, that is, hand tools and manual equipment including chainsaws, to overseas markets.

As regards future development of large logging machines, it may be necessary to match these machines to the requirements of the world market in order to achieve a higher export volume.

CONCLUSION

A charcteristic feature of developments in forest technology in Sweden has been to mechanize difficult operations by introducing technically complex machines. Instead of simplifying, changing or transferring forestry operations to a site outside the woods, in Sweden we have elected to employ a high level of technical expertise to solve the problems facing us in the stands. An exception to this trend was the transfer during the 1960s of the arduous job of barking by hand to the mill, and the mechanized barking at landings that was carried out for a limited period.

From what can be discerned of likely future trends there is a great deal to suggest that the best way of achieving the desired development will be precisely to simplify, adapt and move forestry operations to more suitable conditions. This is largely because of the necessity of achieving fuller utilization of the raw materials from the forest and of reducing the logging costs. Another reason is the new frontiers that are now being crossed in the fields of information processing and automation, thanks to the rapid advances being made in the electronics field.

FUELWOOD PROCUREMENT FOR AN INDUSTRIAL POWER PLANT: A CASE STUDY OF DOW CORNING'S PROGRAM[1]

A. Gray Folger[2]

Phillip G. Sworden[3]

Charles T. Bond[4]

Abstract.--Dow Corning Corporation has developed effective procedures for meeting the fuelwood requirements of a 22.4-megawatt steam and electricity cogenerating power plant. The fuelwood procurement program of Dow Corning's Natural Resources Department involves special arrangements with private landowners, logging and hauling producers, and waste wood suppliers. The program's success is attributable to a favorable location, adequate allowance for advance planning, effective public relations, and flexible management. The program is significant because it demonstrates that industrial fuelwood requirements can be met and that improved production from nonindustrial private forests can be relied upon as a major source of fuelwood.

INTRODUCTION

Two major obstacles confront industrial plants considering using wood as a fuel: assurance of a reliable fuelwood supply and handling of the fuel at the plant site. Dow Corning Corporation is one of the first firms outside the forest products industry to produce energy from wood for large-scale industrial application. In a two-year cost-sharing agreement with SERI's former Industrial Applications and Analysis Branch, Dow Corning was to address problems of fuelwood procurement and handling by

1. Collecting data on test storage of local whole-tree-harvested chips and

2. Reporting on experience gained in planning and developing operational systems for fuelwood procurement, storage, and handling.

This paper reports only on Dow Corning's experience in planning and developing a fuelwood procurement program for the 22.4-megawatt steam and electricity cogenerating (SECO) plant at their facilities in Midland, Michigan.

FUELWOOD REQUIREMENTS

Dow Corning Corporation, an industrial manufacturer of silicone products, replaced two oil-fired boilers for process steam and heat with a wood-fired plant which was started up during the fourth quarter of 1982. The plant consists of a nominal 275,000 pounds per hour (pph) spreader-stoker boiler and a condensing turbine. The unit is designed to burn wood with gas or oil in a 9:1 ratio (by Btu) 11 months of the year. The admixture of natural gas or fuel oil promotes boiler operating stability (i.e., temperature and pressure) for efficient and smooth operation of the turbine. One month per year of down time is planned for inspection and maintenance as required by state law. The annual fuelwood requirements are approximately 165,000 dry tons, which amounts to about 15,000 dry tons of wood per month (±20% depending on the load and season).

The fuel handling and combustion systems of the plant are designed to operate with the variations in particle size and moisture content characteristic of wood fuels. The preferable particle size is a 1-inch chip having typical dimensions of about 1 by 1 by 3/8 inch. However, fuelwood ranging in size from that of sawdust and smaller fine material to a 2-inch cube can be accommodated. The plant is equipped with a wood hog to reduce oversized pieces. The boiler can handle a fuelwood mix containing as much as 20% fines (by dry weight). The boiler is designed for a wood moisture content of 40% (wet basis), but 50% moisture wood, such as is generally characteristic of fresh field-harvested chips, is acceptable.

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[1]Paper presented at the COFE/IUFRO[3] 1984 Symposium, Orono, Maine, USA, 12-14 August.

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Requirements of industrial revenue bonds used to finance the plant dictate the types and sources of fuelwood. Seventy five percent (by dry weight) of the fuelwood must originate from noncommercial, or residue, sources. Forest-derived material from tops and limbs, standing dead trees, and noncommercial species are included, as well as mill residues and urban wood wastes.

Contaminants in the wood fuel are of concern for their effect on equipment and as occupational safety or environmental hazards. Major types of contamination to be avoided are (1) hazardous chemicals, such as the chlorinated hydrocarbons and heavy metals in preservatives and pesticides; (2) demolition rubble, such as glass, brick, stone, concrete, and metal; and (3) miscellaneous contaminants, such as asbestos and other types of insulating materials. With the exception of contaminated wood from forest areas recently treated with pesticides, including herbicides, the major potential wood sources with unacceptable contaminants are urban wood wastes. Limited quantities of mineral soil from field chipping operations are expected.

A limited area is available at the plant site for fuelwood handling and storage. The area designated for open storage of fuelwood can contain a pile of wood about 35 feet high extending over approximately 4 acres, as shown in figure 1. This amounts to a 30-day supply. It is imperative, therefore, that fuelwood be available and deliverable throughout the year without major disruptions.

RESOURCE EVALUATION

Construction of the SECO plant followed several years of investigation, evaluation, and planning. Critical questions involved the availability of wood resources. An internal study team was created early in 1977 to study the feasibility of using wood for fuel, addressing such questions as

- How much wood is there?
- Who owns the wood?
- How available is the wood?
- Who would produce the wood?
- How much competition is there for this resource?

The study team, initially comprised of a manager of engineering support, a utilities specialist, and an accountant, selected a forestry consulting firm to perform resource evaluation studies. A professional forester was hired to help direct and interpret the findings of the resource studies. Specifically, the forestry firm was to

1. Evaluate the economics of using Michigan's wood resources to meet Dow Corning's energy requirements,

2. Identify the wood procurement sources and procedures offering the most dependable long-term wood supplies at a reasonable cost, and

Figure 1.--Dow Corning's SECO power plant and the wood fuel storage pile.

3. Recommend a specific wood procurement system.

In a series of three reports, the forestry consulting firm presented their findings and recommendations. The Phase I report indicated that wood would be economical in comparison with fossil fuels (i.e., gas, oil, and coal). The Phase II report concluded that the potential supply of wood fuel material within a 75-mile radius of Midland is more than adequate to provide almost any desired mix of forest, urban, and industrially derived fuelwood in the quantity required by Dow Corning. The report recommends that

- Dow Corning need not purchase forest land or directly hire timber harvesters,
- Chips should be acquired through purchase contracts with independent producers,
- Brokers should be used to collect urban and industrial wood residues,
- Procurement efforts should be concentrated within 50 to 75 miles west and north of Dow Corning,
- Delivery of wood fuel should be by truck, and
- Prices paid for wood fuel should be based on dry tons.

The Phase III report identified and evaluated wood producers, forest products mills, and large forest landholdings within the procurement area.

The conclusions and recommendations of the forestry firm were supported by forest resource data and analyses presented in several federal and state government reports (Blyth and Hahn 1977, Chase et al. 1970, Manthy et al. 1973, Wood Energy Task Force 1981). Data were compiled on commercial forest land (by ownership and forest type), growing stock volume, net annual growth, timber products removals, logging residues, standing tree residues (i.e., rough, rotten, cull, small, and salvageable dead trees), and mill residues for counties within a 75-mile radius of the Midland plant site. Figures 2, 3, and 4 show pie graphs of commercial forest land ownership, annual forest growth versus removals, and mill residues, respectively.

Despite the limitations and uncertainties of available resource data, the potential fuelwood supply appeared to be adequate in terms of both the physical supply and competition for the resource. Annual forest growth exceeds removals by a wide margin, and the standing tree residue portion of the forest alone contains over 100 times Dow Corning's annual wood requirement. While there are about 80 sawmills of various sizes in Dow Corning's procurement area, the procurement of mill residues and lower-value forest material (e.g., pulpwood) for the SECO plant would offer little competition with major pulpwood purchasers in the Lower Peninsula of Michigan (fig. 5). The predominance of forest land to the north and west

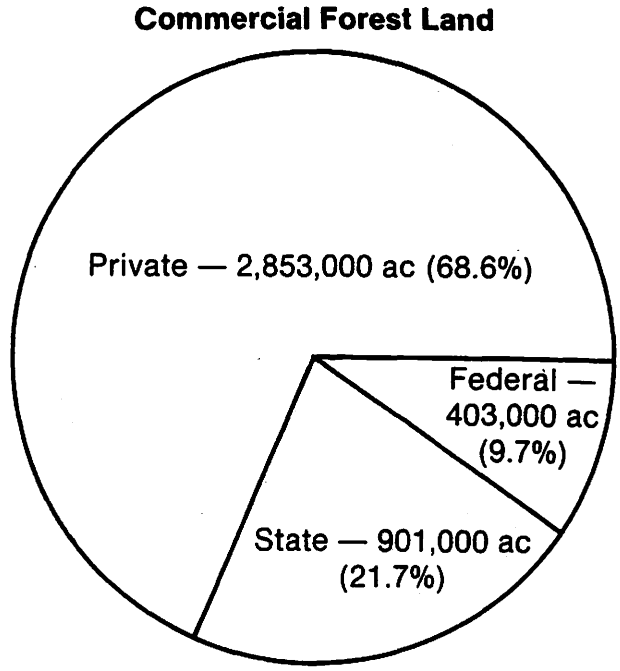

Figure 2.—Ownership of commercial forest land for counties within a 75-mile radius of Midland, Michigan.

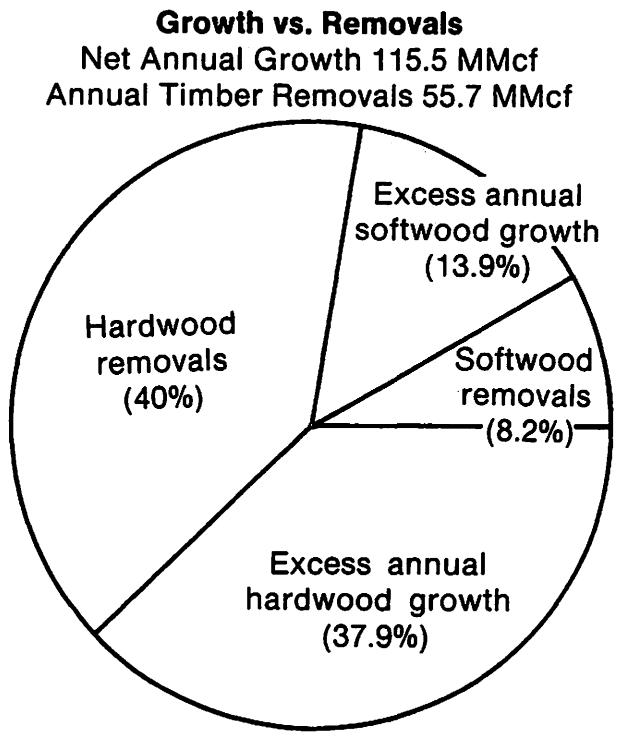

Figure 3.—Annual forest growth versus removals for counties within a 75-mile radius of Midland, Michigan.

of Midland (fig. 6) directed the focus of procurement planning to that area.

The forest stands in the vicinity of Midland consist of natural mixed hardwoods (e.g., aspen, maple, oak, and birch) and planted pines (e.g., red, Scotch, white and jack). In general, the hardwood stands became established following abandonment of agriculture during the 1930's. Much of the forest growth is underutilized and underproductive. Aspen stands, which regenerate from sucker sprouts, are typically clearcut. The pine plantations and hardwood stands are typically managed for pole and sawtimber production, as appropriate, by thinning. Though steep terrain is unusual in the area, site conditions that affect harvesting are soil texture and wetness, which vary spatially and temporally. Low and/or wet areas are, therefore, most accessible during the winter and summer months when the ground is frozen or dry.

FUELWOOD PROCUREMENT PROGRAM

Procedures for wood procurement are well established within the forest products industry. Utility companies and nonforest industrial firms considering the use of wood for fuel are often deterred by the apparent lack of a suitable infrastructure for continuous, long-term (e.g., 20 to 30 years) provision of wood at reliably constant prices. General guidelines for industrial fuelwood procurement are described by Harris and Helms (1981). The program developed by Dow

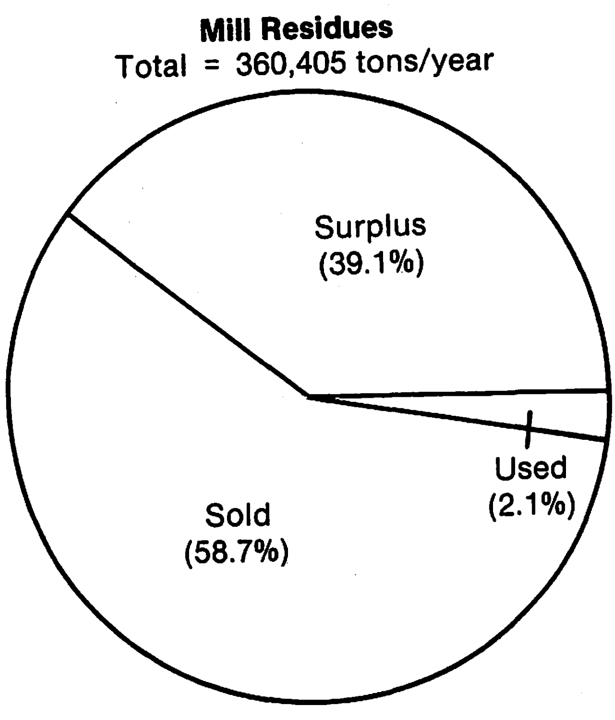

Figure 4.—Annual generation of saw mill residues for counties within a 75-mile radius of Midland, Michigan.

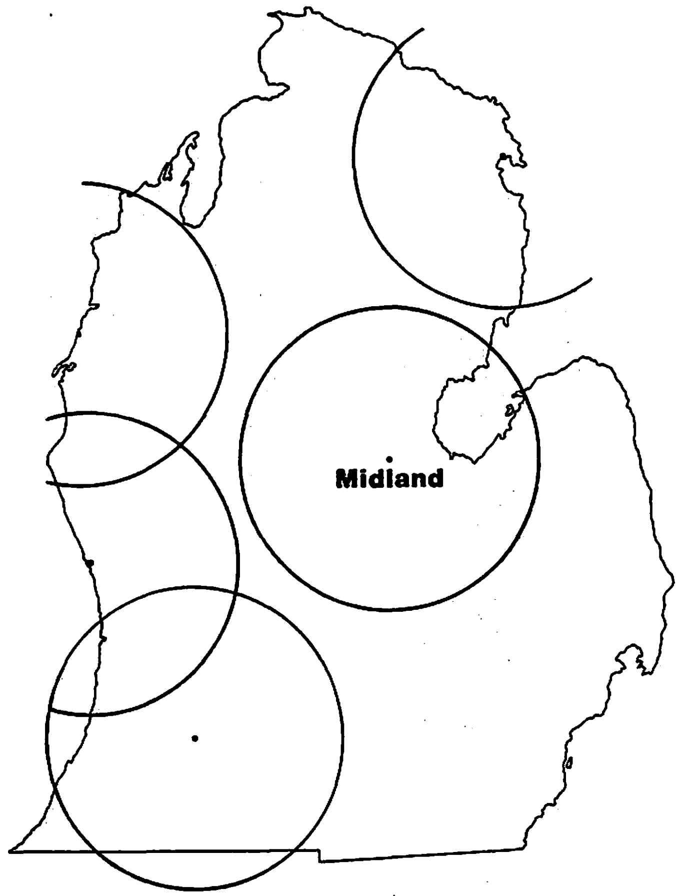

Figure 5.—Circles of 50-mile radius from Midland and from the locations of major pulpwood purchasers in the Lower Peninsula of Michigan.

Corning Corporation is offered here as an example of how, under a particular set of circumstances, it can be done.

The fuelwood procurement program for the SECO plant, in the form that it became established and operational, involves special arrangements with private landowners, logging and hauling producers, and waste wood suppliers--all managed by a small staff of natural resources and procurement professionals. The structure and procedures of the program were developed from investigations and plans over a 5-year period.

In addition to study and planning, effective communications with the public were highly instrumental to the development and success of the program. For example, audio-visual presentations were developed by Dow Corning's public relations department, in conjunction with natural resources and engineering staffs, to explain the power plant project within the context of sound natural resources management. By the time of plant start-up, nearly 200 presentations to about 10,000 people had been made. All inquiries and requests for informational presentations were honored.

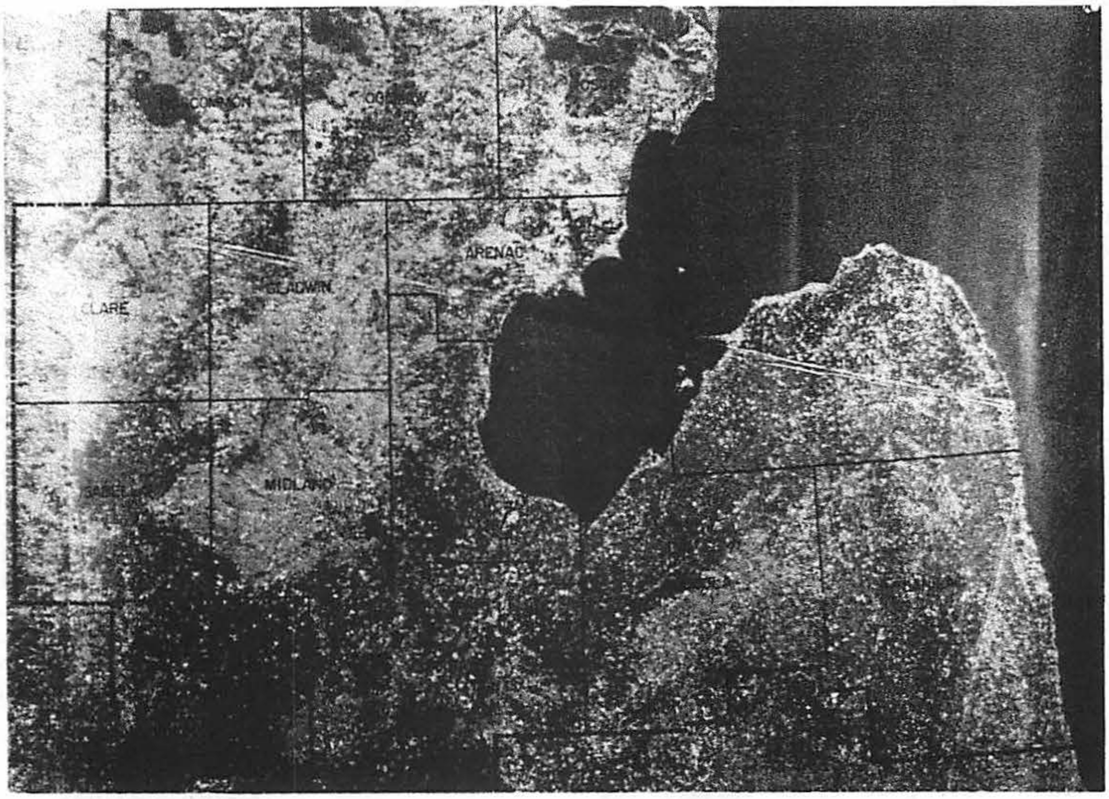

Figure 6.--Satellite image reproduction showing the occurrence of forest land to the north and west of Midland, Michigan, and agricultural land to the south and east.

Private Forest Landowners

The procurement program came to focus on private landowners as an alternative to initial plans for long-term contracts with state and federal land-managing agencies. Responses to a questionnaire sent to selected landowners in 1977, and subsequent contacts and discussion, revealed much interest in forest management, particularly for wildlife habitat improvement. The variety of landowner objectives and the need for individualized attention to ensure proper forest management induced Dow Corning to gradually enlarge the natural resources staff to include wildlife biologists and a field ecologist, as well as additional foresters.

The program with landowners involves land management guidance and assistance before money is exchanged for wood, excluding sawlogs. When a landowner contacts Dow Corning, a meeting is arranged with an appropriate staffperson of the Natural Resources Department to discuss the landowner's goals and how forest management practices can be applied. If in the judgement of the natural resources staff the landowner's tract of timber is suitable for Dow Corning's purposes and the landowner genuinely intends to manage it, an inventory is conducted and a management plan is prepared.

The management plan incorporates the landowner's goals within a framework of sound timber management, wildlife management, and soil conservation practices. The landowner's tract is characterized in terms of soils, vegetation, timber, and wildlife habitat using maps, tables, and descriptions. Management prescriptions include a harvest map and schedule, recommendations for locating access roads, and additional information as necessary for more specific landowner goals such as ruffed grouse management, turkey management, pine plantation thinnings, or special recreational needs.

The immediate intent of a management plan is to facilitate communication and understanding of natural resources management by the landowner. It is provided to the landowner without necessitating any obligation to Dow Corning. Upon negotiation of one or more contracts for Dow Corning to purchase pulpwood from the landowner, the plan provides prescriptions for harvesting that are understood and assumed by both parties. To ensure compliance with the plan, Dow Corning provides assistance by designating sale areas, marking trees to be removed or left, and locating access routes and landings. The plan's specifications are reviewed with the producer before harvesting and are also used as a basis for subsequent periodic inspections of the job.

Logging and Hauling Producers

The forestry consulting firm and the state department of natural resources developed lists of potential chip-harvesting producers for Dow Corning. Dow Corning selected 15 local producers and sent invitations to bid on contracts to harvest and haul Dow Corning stumpage (purchased from private landowners). The bid invitation package included (1) bid instructions and a bid form, (2) a sample contract, (3) general criteria for stumpage to be provided, (4) a form for information on the producer, and (5) a description of Dow Corning's safety requirements. Of the 15 producers contacted, 6 responded and 3 were selected.

This bid approach allowed the producers to specify their preferences for operating locations and tonnages of wood chips to be delivered. A major reason for bidding rather than specifying delivered chip prices was that the operators know best the economics of their own operations. To alleviate concerns about blind bidding on Dow Corning stumpage, criteria for the stumpage to be provided were established. Since the producer contracts are to be effective for a period of 3 years, the bid form and contracts incorporate provisions for adjusting the payment rates per dry ton or per dry ton mile in response to unforeseen escalation of fuel, labor, or other costs. The producers are paid on a dry ton equivalent basis to encourage practices which promote delivery of wood with a low moisture content.

Waste Wood Suppliers

As mentioned previously, a rather large number of sawmills operate in the Dow Corning procurement area producing substantial quantities of residues requiring disposal. Waste wood suppliers (currently mostly sawmills) were selected on the basis of sawmill size, quantity of residues available, and delivered price. Because the production of sawn wood products varies with demand, Dow Corning's contracts allow for 15% to 20% variation in dry tons delivered. Prices paid for mill residues are based on dry tons and a maximum permissible moisture content to encourage handling practices that minimize moisture content. The total amount of sawdust used is restricted by the capacity of the power plant and its wood handling systems to tolerate fine wood particles.

CONCLUSIONS

Dow Corning's industrial fuelwood supply is not absolutely secure in terms of sources and costs for the lifetime of the plant. However, contracts are now in effect with suppliers and landowners for the next 2 to 4 years. What is more significant is that flexible, responsive, and effective procedures are now established that should serve to maintain a continuous supply of fuelwood at reasonable costs in a dynamic market situation.

The apparent success of Dow Corning's fuelwood procurement program is attributable to several factors, not the least of which is a favorable location. Other factors are (1) the questioning and open-minded attitude of Dow Corning's management, (2) adequate allowance of time and expenses for planning, (3) implementation of effective public communication practices, and (4) incorporation of the expertise of natural resources professionals throughout planning and implementation of the project. Continued success of the fuelwood procurement program depends on maintaining an innovative and questioning approach in response to dynamic wood market conditions.

Dow Corning's fuelwood procurement program provides an example of how a nonforest industrial firm can ensure a reliable supply of substantial quantities of fuelwood in a manner that is complementary to the requirements and operations of the forest products industry. It also provides an example of how to facilitate productive management of nonindustrial private forest lands, a question which is often described as the major challenge to forestry in the United States for meeting future wood supply requirements (FPRS 1979, USDA Forest Service 1982).

RECOMMENDATIONS

During the first year of operation of Dow Corning's power plant, a need to improve control of fuelwood moisture content became apparent. Several mechanisms were identified (and are still being refined) which are summarized below as recommendations for industrial firms starting up wood-burning power projects.

- Wood purchases should be based on actual weight, including the moisture content, rather than on a dry weight equivalent--because the latter does not reflect differences of net energy value with moisture content.
- Evaluations of fuelwood resources in planning should also be based on the net energy, or usable Btu, values using relationships between costs and moisture content such as the ones illustrated in figure 7.
- Incentives and disincentives can be used to encourage delivery of low-moisture-content wood.
- Quick and accurate moisture content sampling procedures are needed for receiving and paying for delivered loads of fuelwood.
- The use of sawdust may need to be restricted and carefully controlled because of its tendency to absorb and retain moisture.
- Whole-tree-chipping operations can be planned and scheduled to minimize wood moisture content by considering species, time of year, and site conditions. In

addition, allowing a period of several weeks to elapse between the severing and chipping operations of a harvest reduces wood moisture content by transpirational drying when foliage is present.

General recommendations, drawn from the Dow Corning experience, for planning and developing an industrial fuelwood procurement program are summarized as follows.

- Publicize wood fuel needs early in project development so all sources can be identified.
- Develop an effective, comprehensive public communications program.
- Begin procurement planning and actual procurement as early as possible.
- Use bids in conjunction with specifications instead of fixed rates of payment in formulating arrangements with producers and suppliers.

Finally, two general recommendations are offered, based on Dow Corning's experience, regarding information that would be helpful to those considering industrial wood energy systems.

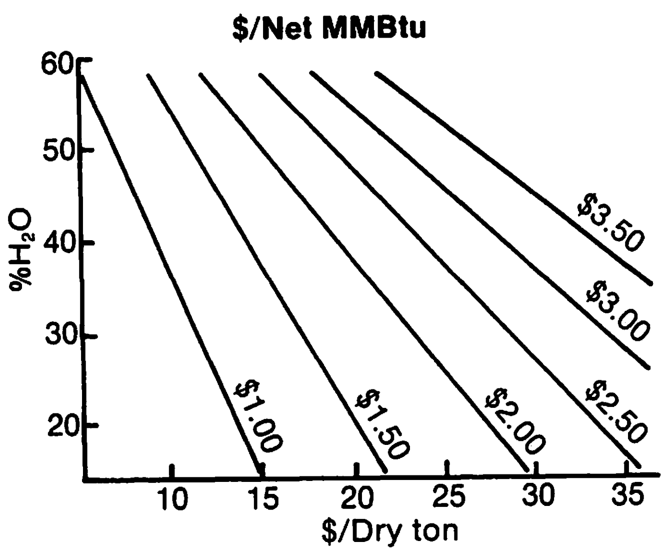

Figure 7.--Relationships between actual energy costs versus dry weight costs of fuelwood as influenced by moisture content.

- Reliable information and data are needed on the total biomass from any given forest and on the material available as wastes from wood utilization and disposal.
- Some central source of information on fuelwood resources, wood fuel characteristics, and energy conversion systems is also needed.

ACKNOWLEDGEMENT

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REFERENCES

Blyth, J. E. and J. T. Hahn. 1977. Pulpwood production in the North Central Region by county, 1977. USDA Forest Service Resource Bulletin NC-34, 22 p. North Central Forest Experiment Station, St. Paul, Minn.

Chase, C. D., R. E. Pfeifer, and J. S. Spencer, Jr. 1970. Growing timber resource of Michigan, 1966. USDA Forest Service Resource Bulletin NC-9, 62 p. North Central Forest Experiment Station, St. Paul, Minn.

FPRS. 1979. Timber supply: Issues and options. Proceedings No. P-79-24, 218 p. Forest Products Research Society, Madison, Wis.

Harris, R. A. and S. A. Helms. 1981. Procurement of wood as an industrial fuel in the southeastern U.S. p. 165-173. In D. L. Klass et al. (eds.) 1981. Energy from biomass and wastes V. Institute of Gas Technology, Chicago, Ill.

Manthy, R. S., L. M. James, and H. H. Huber. 1973. Michigan timber production, now and 1985. Michigan State University Agricultural Experiment Station and Cooperative Extension Service Research Report No. 192, 23 p. Michigan State University, Lansing, Mich.

U.S. Department of Agriculture, Forest Service. 1982. An analysis of the timber situation in the United States, 1952-2030. Forest Resource Report No. 23, 499 p. USDA Forest Service, Washington, D.C.

Wood Energy Task Force. 1981. Wood as an energy resource: Demand, supply, and impact in Michigan. 40 p. Forest Management Division, Department of Natural Resources, Lansing, Mich.

HEATING SYSTEMS IN SWEDEN
WITH ENERGY FROM FOREST BIOMASS

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I INTRODUCTION

Forest Biomass in Sweden is calculated to give 20-40 TWh/year* or 4-8% of the estimated yearly demand of energy in the 1990's.

Table 1. --Consumption of forest fuel for heating of buildings was in 1982 according to below (Skogsstyrelsen - SIND 1983).

	million m^3 solid
Villas	3.3
District Heating	0.3
Forest Industry	0.3
Others	0.5
	4.4 equal to about 6.2 TWh

Total demand of energy for heating of buildings was in 1982 about 100 TWh including district heating with 27 TWh.

One of the biggest obstacles for a fast development of Forest Biomass Energy has been the uncertainties with the economical competition between forest fuel, oil, coal and electricity. Other possible obstacles are soil acidification and nutrient losses. Here a fast increase in the use of forest energy presupposes utilization of the whole tree from cleaning, thinning and clear cutting.

Forest fuel is used today in Sweden with relatively well established techniques which in some cases have faced severe operational disturbances. These are mainly dependent on the forest fuel qualities. Some of the negative factors and problem areas can be listed as follows:

- high and variable moisture content
- contaminated fuel with snow, ice, sand, etc.
- oversized chunks of fuel
- high content of fine fractions below 5mm. Especially for logging residue
- storage and transport

The aim with this paper is to give an overview of Sweden's technical level for combustion of forest biomass in small scale systems and in district heating systems. The last two sections presents the results of a field-study on cooling of the fluegas and a study on burnout time for chunkwood.

* Heating of buildings 1 TWh = 10^{12}Wh $\approx 10^5 m^3$ heavy oil.

II EQUIPMENT FOR COMBUSTION OF FOREST BIOMASS

The theme here is mainly limited to the technical construction of the grate which carries the burning fuelbed in the furnace. Some new combustion systems are discussed in the end (below listed points K-N). In the design of a furnace for forest biomass some of the following fuel properties must be considered.

Fuel Properties

Moisture content

The moisture content of the fuel is measured on green basis =

$$= \frac{\text{weight of the water}}{\text{total weight of the fuel}}$$

Combustion of wet fuel, with moisture content over 35%, can be done with good results in, for example, a furnace with refractory lining which dries the fuel before combustion. Forest fuels with moisture content over about 50% needs normally preheating of the air for good combustion. Maximum moisture content is below 65-70% that will support a good combustion.

Size

A high content of fine particles in the forest fuel can create an uneven air distribution over the grate and increase the amount of unburnt fuel which is carried with the fluegas to the boiler's convection part and the smoke cleaning equipment. The unburned material in the ash also increases with the amount of oversized chunks in the fuel. Uneven, "stringy" and "sticky" fuel can hamper the proper flow to and in the combustion bed.

Ash and contaminants in the fuel

The ash content is measured on the dry weight of the fuel.

High ash content in the fuel increases the risk for cindering. Sand and stones in the fuel increases the wear on the grates and on the materials handling equipment.

Variation

Variation in bulk density, moisture content, ash, contamination and size makes it difficult to maintain an even and high combustion efficiency with low smoke-emissions. Variations in the fuel causes adjustment of the fuel bed parameters, such as:
- speed and thickness of the fuelbed
- air preheating and distribution
- combustion temperature

The following briefly describe the most commonly used combustion systems in Sweden.

A. Plain fixed grate in a preoven or a water cooled furnace

This grate system is common for boilers below 1-5 MW and gives a safe operation except for fuel with a high ash content which gives problems with cinder formation. Fuel in the shape of billets are usually fed manually into the furnace whereas chipped fuel is fed with automatic equipment. The ash is normally removed manually.This is even done every day in one 30 MW district heating plant with a cyclone-preoven stoker fed on flat grate. The cyclone preoven has proven a reliable and efficient way of burning woodfuel.

B. Plain reciprocating grate

The plain aircooled reciprocating grate is not so often seen in Sweden but can be used as above for A, and for even bigger power demands. The grate can be used for bark, chips and logging residue with maximum ash content of 5-10% and moisture content 20-60%.

C. Inclined watercooled grate

This grate is normally used in big scale systems for chips and wood residue, sometimes even for bark. The grate works well for fuel with a low ash content - below 1-2% - and with a moisture content below 50-60%.

D. Inclined watercooled grate with reciprocating grate in the end

This combination grate type is used as C but with higher ash content (3-5%) in the fuel. The moisture content should be above 20% because of the air cooled movable grate.

E. Inclined aircooled grate

This grate has many different shapes including the conical type with or without the plain final combustion grate. The inclined aircooled grate is used as in C and D.

F. Reciprocating inclined grate

Reciprocating inclined grates are highly suitable for forest fuels with ash contents below 10-20% and moisture content in the range of 20-65%.

G. Rotating plain grate

This newly developed construction has a rotating grate where the fuel is fed from the perimeter. The fuel is then directed against the center of the inward sloping grate where the ash and the cinder is taken out. The rotating speed of the grate can be varied according to type of fuel. The surface of the grate is closed against ash downfall. The grate will then be suitable for fuel with a high content of fine particles. The grate is used in a preoven for fuel with a high moisture content of 55-60% and ash content of 10-20%.

H. Wander grate

Wander grates are used only in a few plants in Sweden mainly for coal. Some tests have been done with a mixture of wood and coal. Results so far have been on the positive side in reducing SO_2-emission. A large amount of wet wood can give difficulties with ignition and gasification of the fuel. A wander grate for only forest fuel needs certain special provisions to get higher combustion temperatures. Two examples are fluegas circulation and refractory heating surface. The moisture content should be less than 25%. A relatively large ash content, 10-20%, can be acceptable.

I. Spreader stoker with travelling grate

Spreader stokers are only used in a few plants in Sweden. This type of system has the advantage that mixing of different fuels can be done simultaneously during the firing. The moisture content ought to be below 50-55%. Relatively high ash contents, up to 5-15%, can be tolerated.

J. Small scale system

Small scale systems, below 100 kW, are usually fired manually with the billets on a plain grate in a water cooled combustion chamber. The moisture content of the logs are, for good firing, below 20-25%. Better combustion is achieved in a furnace with ceramic lined wood burning box. The ceramic furnace (fig. 1), can even be equipped with fluegas cooler. Total furnace efficiency, based on higher heat value, can then be increased from 60-70% to 85-95%. This furnace can use wood with moisture content within 15-50%.

The new limits for emission of tar, in small scale combustion, is set to 10 mg/MJ. This limit can today only be met in a handful of ceramic furnaces. Conventional furnaces with water cooled fire chambers often have tar-emissions in the range of 500-1,000 mg/MJ.

In small scale systems using wet chips, with moisture content of 35-55%, firing is done in a bricklined combustion chamber placed before or in the furnace. Feeding of wet fuel can be done with a gravity system or with an automatic stoker with retort. Dry chips, below 25%, are normally fed with an automatic stoker to the retort which is placed in a water cooled combustion chamber. The ash content in the fuel is usually low in small scale combustion system: - below 1-2%.

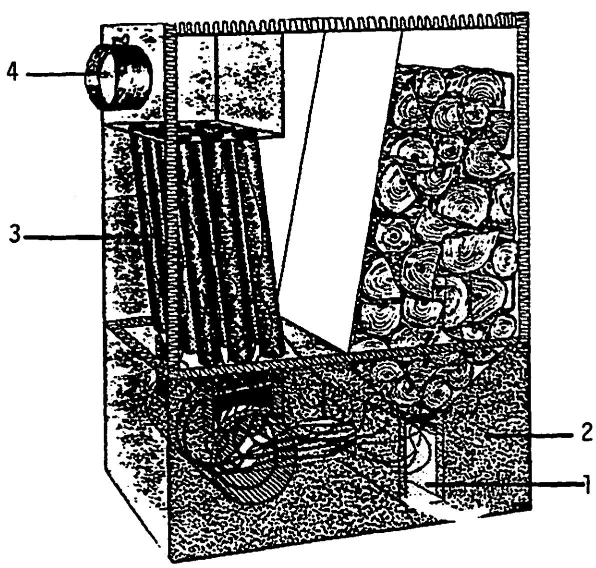

Figure 1. -- Ceramic furnace. 1. Fire chamber, 2. Ceramic, 3. Water cooled tubes, 4. Chimney.

K. Combustion of densified fuels

The most common products are briquettes and pellets. The first is used in ordinary combustion equipment for dry forest fuel, for example with an automatic stoker with a fairly oversized auger.

Pellets have proven to be difficult to combust. One reason is that the burnout time for pellets is 2-3 times longer than that of chips. Pellets also give problems with cinder formation. Combustion of pellets have been more or less succesful with some kind of moveable grate. One example is a rotation combustion basket (fig. 2). Another solution has a high temperature burner with an hydraulic pusher which removes the melted cinder and ash.

L. Combustion with wood powder

Firing with dried and ground forest fuel is used by only a few of the bigger heating plants for industrial and district heating. Powdered wood firing has an advantage because existing oilboilers can easily be converted to forest fuels. Disadvantages are the risks for explosion and the high cost for the wood powder.

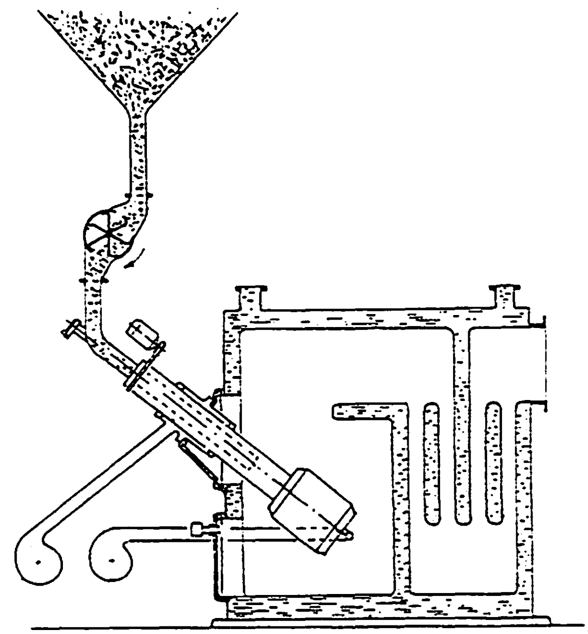

Figure 2.--Pellets burner with rotation combustion basket.

M. Fluidized bed

About a dozen fluidized beds have recently been installed in Sweden. The technical solutions differs from the simpler bubbling bed to the more complex fast circulating bed or double bed. The latter has the fuel supply in the lower bed with final combustion in the upper bed. Efficiency and smoke-emission with different woodfuels have shown good results but to the price of a complicated technical solution.

N. Bio turbo system

The Bioturbo system (fig. 3) is under development for burning of wet fuel. Combustion of the fuel and cooling of the fluegas is done under pressure. Hereby the water vapour in fluegas condenses at such a temperature that the main part of condensation heat can be used in a heating system.

Combustion air is compressed in two steps, high- and lowpressure compressors. Combustion takes place at a 7-8 bars overpressure in the fluidized bed. The air is blown in from the bottom and fuel feeding is from above the air intake. The fuel then floats on the air flow while it is being combusted.

The hot fluegases pass a couple of cyclones for dust separation before they are conducted into a gas turbine which drives the high pressure compressor. After the high pressure turbine the flue gases are conducted in a heat exchanger which heats water. All remaining energy in the gases is taken out in a second turbine which drives the low-pressure turbine. This system is technically complicated but its thermal efficiency, around 85-90%, is independent of the moisture content of the fuel up to about 80%.

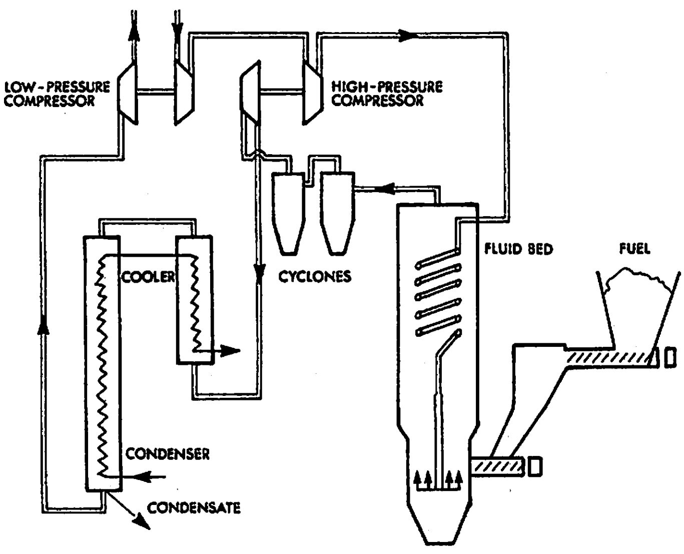

Figure 3.--Bioturbo system.

III FLUEGAS CLEANING, ASH REMOVAL AND SOOT CLEANING

A. Fluegas cleaning

The most common systems for fluegas cleaning in heating plants over 5-10 MW are:
- electrical filter has high efficiency with high equipment cost.
- textile filter with prefilter has the highest efficiency and high equipment cost. Combustion of forest fuel can result in increased risk for fire in the filter.
- multicyclones with secondary separator have medium efficiency with relatively low equipment cost. Fluegas cleaning in smaller furnaces below 1.0 MW is mainly done with multicyclones.

Small furnaces and stoves below 0.1 MW, often used in villas, farmhouses etc., have normally no cleaning of the smoke. Emissions to the air from a small billet furnace with watercooled firechamber are 10-100 times greater than a furnace with good combustion. Good burnout of heavier wood components, such as tar, demands a temperature above 800°C. This can be done in a combustion chamber with a refractory lining of bricks. In order to avoid smoulderfire, with high air pollution, a small furnace should be connected to an accumulation tank.

B. Ash removal

Outfeeding of slag and ash from bigger furnaces is often done through a waterbath in order to put out the live coal. Smaller plants use dry outfeeding system which have relatively low equipment cost. The smallest boilers use manual ash and slag removal. Materials handling equipment for slag and ash demands very heavy constructions in order to avoid shut down. Screw feeders should be avoided where there is a high risk of jamming and wear.

C. Soot cleaning

Sweeping of bigger boilers have worked best with steam. Some boilers accomplish sweeping with low frequency sound with good results. In smaller furnaces below 1-10 MW the sweeping is normally done manually.

Boilers with vertical tubes have less tendency for clogging by soot compared to those with horizontal tubes.

IV MATERIAL HANDLING

Shut down of materials handling equipment is mainly dependent on the properties of the fuel. Some causes are:
- oversized fuel
- valving
- freezing
- contamination (stones, sand etc.)
- varying moisture content
- varying bulk density
- varying primary product

A. Screening

Smaller plants for forest biomass which normally do not have screening device, often use fine comminuted shear-cut chips with a length under 50 mm.

Bigger heating plants normally have a screening device - for instance a disc screen - thus a coarser fuel can be used. Crushed fuels can have a length to 150 mm with some exceptional oversized pieces up to 300-400 mm. The fuel thickness for crushed fuel is normally within 50 mm diameter.

B. Valving

Forest fuels have a high tendency for hanging and valving. These phenomena usually occur in the transport system at changes in elevations for feeders and fuelbins. Sensitive parts for valving should be lined with low friction materials and the walls should, if possible, be inclined inwards against the fuel. Stirring equipment can be used to prevent bridging.

C. Freezing

The tendency for wood particles to freeze together into clumps or to freeze on the surface of piles increases for heating plants located in the north. Freezing can be reduced through a faster storage turnover.

The freezing of fuel to the walls in the storeage container can be reduced by lining it with a low friction material. Frozen clumps of fuel can also be crushed with a special roller with cutting teeth placed in the outlet of the store.

Some receiving silos have been equipped with heating. However, freezing can still occur when the fuel, with low turnover rate, is piled up in a high stack. The lowest risk for freezing is in a store with a low pile height with high turnover rate and heating of the walls and bottom.

Crushed logging residue is much more sensitive to freezing compared with chips from stemwood.

D. Conveyors

Safe operation of forest biomass heating plants are dependent on the construction of conveyors. This gives less reliability in an increase of:
- the length of transport
- the number of mechanical handling devices
- the number of changes in direction
- the speed of transport
- the amount of oversized fuel

Larger plants should be equipped with a small reserve feeding silo which is placed as close as possible to the boiler. The reserve silo can usually be filled with a tractor-loader.

E. Heating plant in Garpenberg

In Garpenberg, the Swedish University of Agricultural Sciences has installed a district heating plant for forest fuel. (fig. 4). The furnace is also intended for test firing with different wood- and peatfuel. The materials handling of the forest fuel in this plant is done after a new concept in Sweden -- an automatic crane equipped with a grapple bucket. This system gives possibilities for combustion tests with different fuel mixes.

The bricklined preoven has an inclined reciprocating grate. The speed of the grate, the feeding of the fuel and the combustion air with necessary preheating can manually be adjusted according to the moisture content and heat demand.

Heating power:	0.75 MW
Pressure - primary circle:	6 bar
Temperature - primary circle:	+ 140°C
secondary circle:	+ 90°C
Fuel moisture content:	25-60%
Fuel size maximum:	400 x 100 x 25 mm or 150 x Ø 200 mm
Ash content maximum:	10%

V FLUEGAS COOLING IN A SMALL FURNACE

A. Background

During March/April 1984 a chip fired furnace with fluegas cooler, figure 5, was tested at a farm near Garpenberg. The chips were fired in a gravity feed brick lined preoven connected to an ordinary water cooled furnace with maximum power of about 25 kW. The heat transmission area in the furnace was 2.2 m^2. An oversized fluegas tube cooler - size $8m^2$ in stainless steel - cooled the gas down to about +30°C during the whole test period of 30 days. The furnace has been fired with chips since 1964. The fluegas cooler was installed 1980.

B. Testresults

Three different forest fuels were used during 10 days each:

Test 1	50% alder and 50% mixture of spruce, birch and aspen. Moisture content = 25%.
Test 2	100% birch. Moisture content = 35-40%.
Test 3	50% spruce, 35% aspen and 15% mixture of alder and birch. Moisture content = 30-35%.

Temperature

Outdoor temperature was on the average -3°C with variations (-15°C to +5°C).

Water temperature in the boiler averaged +80°C.

Fluegas temperature after the furnace before the fluegas cooler varied from +150°C to +320°C.

Gas analysis

CO_2	average 11%
CO	average 0.04%

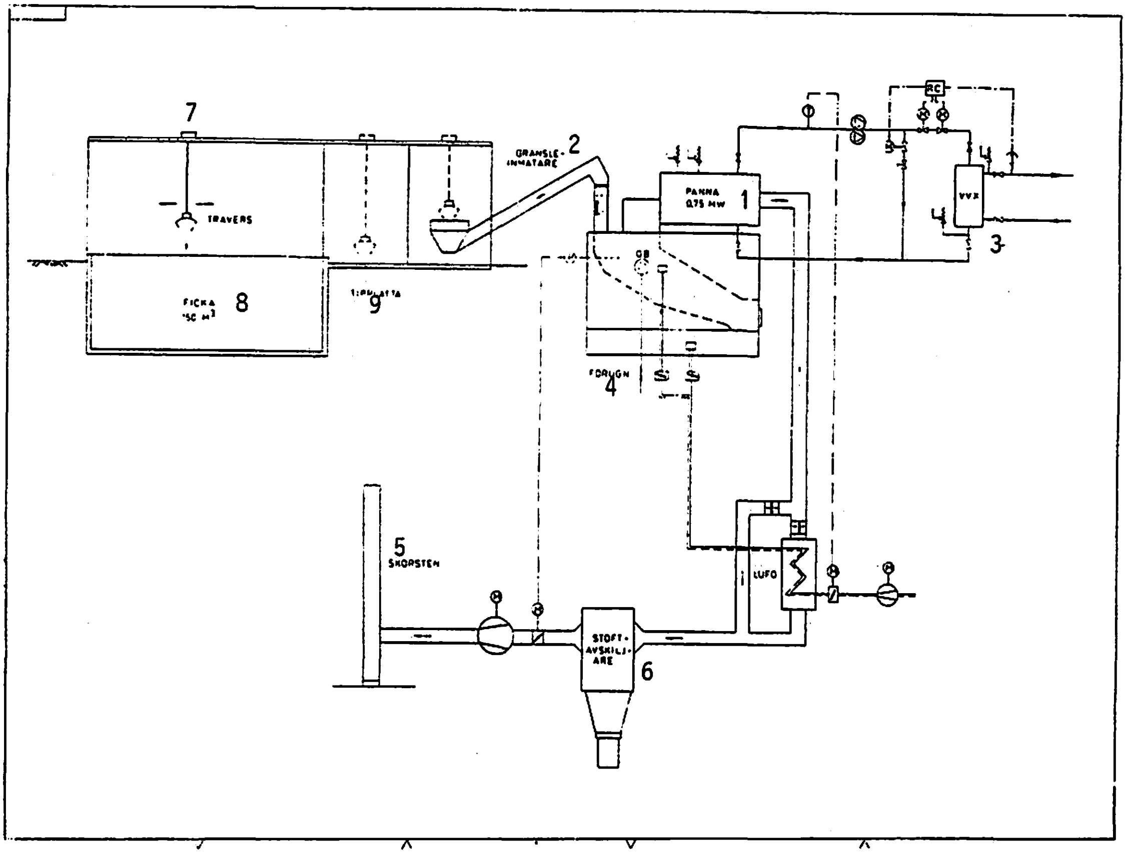

Figure 4.--District heating plant for forest fuel. 1. Boiler. 2. Fuel feeder. 3. Heat exchanger. 4. Preoven. 5. Chimney. 6. Cyclone. 7. Crane w grapple bucket. 8. Fuel store. 9. Test fuel store.

Power

The average output power from the furnace was 13.7 kW.

The average output power from the fluegas cooler was 4.5 kW.

Maximum estimated power from the fluegas cooler was between 7-8 kW.

Efficiency

Average efficiency for the period was:

furnace	63%	with variations from 52% to 73%.
fluegas cooler	20%	with variations from 16% to 26%.
total	83%	

The efficiency is measured on the higher heating value.

Moisture content and combustion

The preoven worked best with a moisture content above 35%. That was clear from the increase of fluegas temperature after the furnace. Test 1 with fuel moisture content of 25% gave an increase of around +120°C after 10 days following sweeping. Test 2 and 3 with moisture content 35-40% gave, during similar time, an increase of around +30°C to 40°C.

Sweeping

The importance of regularly sweeping the furnace must be pointed out. In spite of relatively good operation of the preoven, even a short period of 10 days following sweeping can cause a substantial decrease (5-15%) in efficiency.

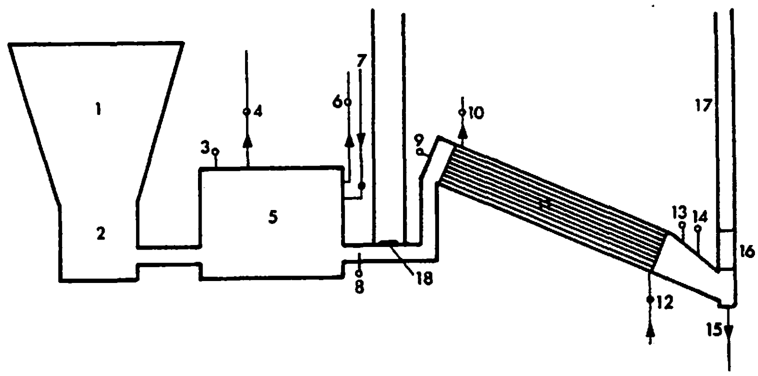

Figure 5.--Chipfired furnace with fluegas cooler. 1. Gravity chip feeder. 2. Preoven - brick-lined. 3. Thermometer for furnace water. 4. Flowmeter for household hot water. 5. Furnace. 6. Energy meter for heating water to the house. 7. Return pipe from the house. 8, 9. Fluegas thermometer. 10. Energymeter for heating water to the stable. 11. Fluegas cooler. 12. Return pipe from the stable. 13. Fluegas thermometer. 14. Fluegas air pressure meter. 15. Condensate pipe. 16. Fluegas fan. 17. New chimney of sheet metal. 18. By-pass damper. 19. Old brick chimney.

Condensate water

The fluegas condensate water was tested (table 2) where some swedish standard values for drinking water and fresh sweetlakewater are included. The amount of condensed fluegas water varied 2 to 3.5 l/h depending on the moisture content in the fuel. The analysis showed low values except for nitrogen dioxid which was far above the limits for drinking water. However, this water will be accepted for a normal sewage system, and it would be more serious to make these emissions airborne.

VI BURNOUT TIME FOR CHUNKWOOD

A. Background

Chipped fuel from wet forest biomass has a big disadvantage in terms of maintaining good quality during long storage time. Wet chips should be consumed within 2-4 weeks in order to avoid disturbing losses in energy and attacks from hazardous fungi.

The long-term storage quality for comminuted wet wood improves with the size of the fuel. Bigger fuel particles have less area for oxidation and fungi and have a lower air resistance for the drying air. Chunkwood can, in small scale systems, even be sun- and winddried. Surface and volume proportion between chips - say 25 x 15 x 6 mm - and chunkwood - 150 x Ø 100 mm - is for the surface 1:51 and for the volume 1:524.

The use of chunkwood as a fuel for heating needs to be proved. In Garpenberg, chunkwood research programs have begun seeking answers to questions like:

- Which type of materials handling and combustion equipments are suitable? Can conventional chipfired plant layouts be used?
- How does the combustion process with chunkwood differ with methods of comminution? Can the influence of cracks in the chunkwood increase the combustion rate?
- What are the figures for efficiency and losses for combustion with different types of chunkwood in a conventional furnace? Will it be a heavy increase of the unburnt particles in the ash?

As a first step to answer the above questions, a burnoutest was started in the summer of 1984. Burnout time is an important design factor for the furnace. The burnout time of the fuel decides the speed of the fuel in the combustion bed. This speed gives normally, for chips, a stay on the grate of around 15-30 minutes.

B. Test oven

Our test oven (fig. 6) has a sheet metal case on an insulated combustion chamber. The lining consists of a ceramic casting for a maximum temperature around 1400 - 1500°C.

The undergrate air is introduced either with natural draft damper or with a fan. The temperature of the oven is measured in point A. Fluegas analysis is done in the beginning of the chimney at point B.

C. Testprocedure

The oven was heated to a temperature around +600°C in point A. Thereafter the oven was loaded with about 8 kg in dry matter weight of fuel. The test wood was set afire with a gas torch until full fire was obtained. This usually took about 5 minutes. The fuelbed was stired every 10 minutes to fully cover the grate. The CO_2 content was

Table 2.-- Analyse of fluegas condensed water

Description		Test 1	Test 2	Test 3	Limits drinking water	Limits sweetlake water
pH		6.8	6.2	7.4	7-9.5	6.5-8.5
Phosphorus P	µg/l	610	530	360	300	-
KMn04	mg/l	160	120	230	20	-
Ammonium						
NH4	µg/l	90	100	16	500	200
Nitrogen Dioxid N02	µg/l	8600	11000	13000	20	-
Nitrate+Nitrite (N03+N02)	µg/l	17000	12000	10000	10000	-
Nitrogen total N	µg/l	47000	31000	64000	-	-
Chloride Cl	mg/l	8	39	5	100	20
Sulphate S04	mg/l	103	56	73	100	200
Aluminium Al	mg/l	0.021	0.021	0.018	0.15	-
Lead Pb	mg/l	0.0014	0.0023	0.0014	0.05	0.01
Iron Fe	mg/l	0.02	0.11	0.027	0.20	-
Cadmium Cd	mg/l	0.0044	0.0092	0.0052	0.005	0.0002
Calcium Ca	mg/l	21	13.3	14	100	15
Potassium K	mg/l	72	29	75	10	0.5
Copper Cu	mg/l	0.0051	0.011	0.0079	0.05	0.02
Chromium Cr	mg/l	0.026	0.0089	0.030	0.05	0.02
Magnesium Mg	mg/l	5.2	2.2	2.5	5	-
Manganese Mn	mg/l	1.0	0.58	0.54	0.10	-
Sodium Na	mg/l	0.57	0.33	28	50	0.1
Zinc Zn	mg/l	5.6	5.0	2.1	1	-

checked before and after the stiring and necessary adjustments with the draft were done. Only primary unheated undergrate air was used. The CO_2-level was kept to about 7% during the main combustion when the wood was gasified. The air draft damper during final combustion of the live coals was kept unchanged from the rate in the end of the main gasification. That gave CO_2-levels in the final stages around 2-4%. For chunkwood with a diameter of 174 mm it was only possible to obtain CO_2-levels for the whole firing period of 4% depending on the big airleakage between the chunks. The burnout time was measured from full fire until most of the live coals passed through the 8 mm slots in the grate and the grate was covered to less than about 20%. The remaining ash and unburnt material was about 3-5% of the dry weight.

D. Results

The chunkwood tested was derived from stemwood of birch and produced with a hydraulic knife. The amount of shear cracks increased with decreasing diameter of the chunkwood, where the cross-section of 174 mm had almost no cracks and the section of 50 mm was covered with several small visible cracks.

Chipped sawmill spruce residue had an average size of 25 x 15 x 6 mm. The burnout test is in its beginning but the result so far (see fig. 7) indicate, as expected, a big difference between chips and chunkwood. This difference might be reduced with chunkwood from a new machine which gives more shear cracks.

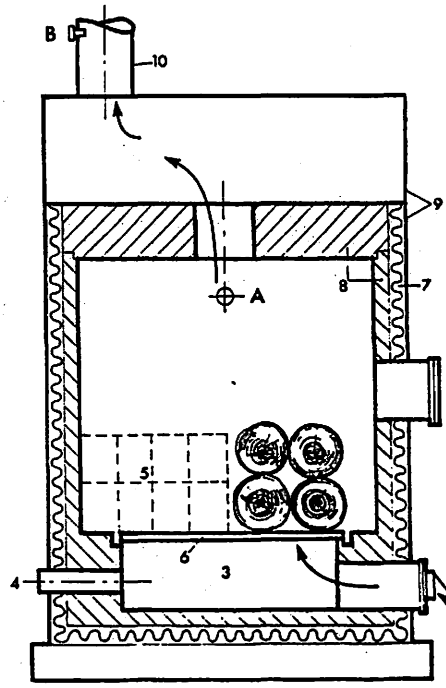

Figure 6.--Testoven. 1. Draft damper. 2. Charge door. 3. Ashroom. 4. Fan connection. 5. Bricks for space adjustment. 6. Grate. 7. Insulation. 8. Ceramic casting. 9. Sheet metal case. 10. Chimney.

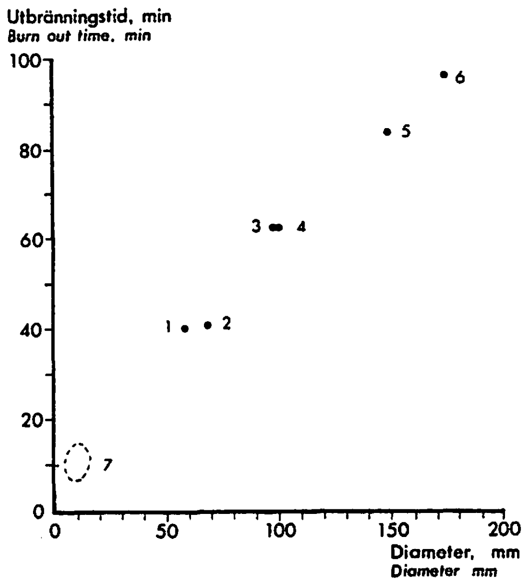

Figure 7.--Burnout time for chunkwood.

Test	Average size mm	Moisture content	Dry weight kg
1	Ø 58 x 158	35	8.07
2	Ø 68 x 148	36	8.12
3	Ø 98 x 146	35	8.34
4	Ø 99 x 148	40	7.58
5	Ø148 x 150	34	8.06
6	Ø174 x 152	36	8.73
7	25 x 15 x 6	33-40	7.84-8.37

VII CONCLUSION

A. Consumption of forest fuel

Consumption of forest fuel in Sweden for heating is still low and an increase of around 3 to 6 times is necessary in order to fulfill the target in the 1990's. Today this seems to be unlikely, it depends on how heavy the competition will be in first hand from nuclear produced electricity.

B. District heating

District heating plants for forest fuel have, in Sweden, a large variation in the technical design from the simpler pre-oven to the complex double fluidized beds. Example on combustion systems with good operational results are cyclones, reciprocating grate and spreader stoker.

Materials handling of chips often will be done with hydraulic pushers and different types of conveyors and screening devices. A relatively new concept is materials handling with an automatic crane with a grapple bucket. This is even suitable for coarse fuel such as chunkwood.

C. Small scale systems

In early times the conventional log firing has been in water-cooled furnaces with low efficiency. A new development, for good combustion, is a furnace with ceramic fire-chamber. This furnace works best in connection with an accumulation tank.

Dry chips are stoker-fired in a water-cooled furnace. Wet chips are fired in a gravity fed or stokerfed pre-oven.

Combustion of briquettes can be easier done compared with pellets which need a higher technical level on the equipment.

D. Flue-gas cooling

One method to increase the efficiency in woodburning is flue-gas cooling. An increase in efficiency around 15-25% is possible even in small furnaces, below 100 kW.

The condensate water from the flue-gas seems to be acceptable for the normal sewage system.

E. Burn-out time for chunkwood

The relatively high time difference between chips and chunkwood indicate combustion difficulties for coarser fuel fed to a standard furnace for chips. However, improvements might in chunkwood comminution and -combustion equipment be able to solve the problem caused by the high burn-out time.

F. Recommendations for future research

In the field of forest fuel handling and heating some areas for future research needs can be recommended.

1. Basic studies of forest fuel in sizes from sawdust to logs and bales:
   - fall down angle
   - slide angle
   - freezing
   - bridging and hanging
   - filling rate of storage-bin in different transport systems
   - combustion: burn-out test, fuel-mixes, condensate rates etc.
   - corrosion
2. Continued or expanded studies of forest fuel in the follwoing areas:
   - health hazards
   - water- and smoke emissions
   - storage, especially for chunkwood, bales and bundles
   - combustion in district heating and small scale furnaces

- drying
- screening
- densified fuel
- comminution
- materials handling
- fuel specification and economical terms

3. Feasibility studies and test of whole fuel systems with:
   - chunkwood
   - bales and bundles
   - whole tree and logging residue fed to a furnace with an automatic crane system.

FOREST ROAD BALLAST & SURFACING ROCK[1]

William A. Johnson[2]

Abstract---Finding and developing quality rock quarries for Forest Roads is essential to orderly, cost-effective transportation planning and development. A methodical, systematic process that utilizes the technical skills of several professions can be effective in producing a Rock Development Plan. Environmental and cost benefits will be dramatic.

It is interesting to note the different disciplines the Forest Engineer gets involved in, and I can't help but recall the paper last year saying that the Forest Engineer should decide what aspect of engineering he will do and then do it well; cut out a piece and be the expert.

In the Pacific Northwest, the Forest Engineer is a specialist who works mostly with land boundaries, logging methods, road layout, construction and maintenance. He is an engineer who works in the forest and whose responsibilities require a working knowledge of roads, bridges, slope stability, pit development, etc. The Forest Engineer is like a small town doctor, handling all cases, and passing the more complex on to specialists.

Before I get into my topic, Forest Road Ballast and Surface Rock, I'd like to tell you of my organization, the State of Washington Department of Natural Resources. My agency is basically a land management agency. We manage 5 million acres of State-owned land. You will recall that upon becoming a state, the Federal Government gave each state sections of land, Section 16 & 36, in each Township. The new state of Washington also received lands to build a university, an agricultural and scientific school, capital buildings and penal institutions. We also manage tax-forfeited land for the counties. Some states sold this land and used the money for development. Other states, such as Washington, kept the land and held it in trust for specific uses, such as Common Schools, State Universities and Colleges, Capital Buildings, penal institutions, etc. We call this Trust Land Management.

The 5 million acres held by the State of Washington includes 2 million acres of forest land, 2 million acres of aquatic land (i.e. beds & shores of navigable rivers & lakes, tidelands and beds of the salt water and harbor areas) plus 1 million acres of commercial and agricultural lands. My agency conducts its proprietary programs from a precentage of the money received from the sale of materials from the land and from leases to use the land. The sale of timber is the biggest source of income, but leases for agriculture and aquaculture are destined to play a larger role in supporting our proprietary programs.

In the development of the 2 million acres of forest land, we have built about 12,000 miles of road. Each year we add approximately 200 miles. Most of these roads are all-weather haul roads that are constructed to support the hauling of large loads. Many areas receive 60" of rain per year and some in excess of 140" per year. This brings us to the point of my discussion "Forest Road Rock."

As you might imagine, we do not often have the rock where the roads are; or, if we do have the rock we need to wisely use it to prolong our source to get the most from it. Rock is one of the largest components of new road construction costs, quite commonly ranging between $35-$50,000 per mile. So, in order to reduce costs, effective planning, exploration, and use of rock resources is necessary. This may mean using soft rock that would degrade rapidly as ballast and then, covering it with harder rock as a wear course. We also use softer rock on one-shot spurs whenever possible.

So now we have the stage quite well set. I want to explain to you the process we are perfecting at the Capitol Forest. In our 80,000 acre Capitol Forest Area outside of Olympia, we have limited proven reserves of good rock, quite an extensive management program, including heavy timber removals, plus a large recreational program.. The forest manager needs good roads to move timber and the recreational public year-around, without degrading streams through road surface runoff, or damaging subgrades. The manager must

[1]Paper presented at the conference of COFE/IUFRO - 1984. Orono, Maine, USA, 12-14 August.

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do this while minimizing road construction and maintenance costs.

1. Rock Need Review

The Department's seven Area Managers ask for input from the local unit managers on surface and ballast rock needs. How many cubic yards of rock will be needed for construction of new roads and maintenance of existing roads each year for the next 10-15 years? Where are the existing pits? Will they meet the demand? In the Capitol Forest we had a problem. We had a large area with few proven sources, heavy construction and maintenance demands, long distances from pit site to delivery point, and several extremely sensitive streams near heavily used roads. In addition to timber hauling there was heavy recreational use. We had all of the ingredients of an expensive difficult problem.

The Forest Engineer was called in. The engineer sized up the problem and determined the assistance of a geologist and soil scientist was needed. Using Management input, a list was prepared identifying the location and volumes of construction and maintenance rock demand. Management then prioritized the list and identified areas needing further study.

2. Literature Search & Review

The engineer and geologist then searched for and reviewed existing geotechnical literature pertaining to the area in question. Additional information, such as well logs or aerial photographs were studied.

A thorough study of these source documents will be used to make a first cut of sub-regions for closer examination. By studying various geological characteristics, such as, structure (faults & folds); geomorphology (land forms); petrology and mineralogy (rocks & minerals); soils (mostly for overburden depth), and even vegetation, we can gather valuable information that will begin to identify areas of interest.

3. Sub-Regional Exploration

The office literature and map review will be followed by intensive sub-regional investigation and evaluations. Sub-regions will be explored on the ground by road, trail and cross country hikes. Continuity of potential rock source strata is mapped. Potential quarry sites are located using rock quality, developability and location as criteria.

Rock quality is estimated using field and lab techniques. Field methods are based mainly on the Uniform Rock Classification for Geo-Technical Engineering Purposes, by Douglas A. Williamson. Laboratory investigations include standard wear tests and petrographic analysis. The latter utilizes the petrographic microscope to study thin sections of rock and yields information such as the mineralogical (and consequently chemical composition) as well as important textural information.

Developability of a site is rated using such criteria as topography and overburden depth. A site should have room for crushing plant location, waste area, and favorable slopes for efficient excavation of rock and overburden.

Overburden thickness is determined by using a backhoe, portable seismograph, or small portable drills such as the cobra drill.

Location of rock sites is of course very important, as rock haul distances add up quickly and effect costs.

4. Site-Specific Investigation

Sites determined to have a very high probability of containing quality rock were examined intensively. Sample rock was sent to the Department of Transportation Materials Lab. Cobra-drilling and/or excavation were used to determine over-burden depth. More thin sections were sometimes made from promising outcrops. Finally, a large scale (1"-50' with a 5' contour interval) map was made. This topog map became the base for overlaying field-generated geological cross-sections that were run to predict rock unit boundaries. This procedure, the heart of the whole investigation, yielded very detailed preliminary geology maps of the potential quarry sites. The maps predicted the quality and extent of each rock unit in the formation. Recoverable base lines and bench marks were established, so that any future work could be tied to the original map.

With favorable lab results the sites were then scheduled for test core drilling. Staff geologists selected drill sites to yield maximum information with the fewest number of holes. Drilling generally indicated the practical operational limits of the site, the location of the optimal first entry, and the boundaries of each rock unit.

Drilling results were then used to confirm or modify the geologist's preliminary map. Core samples were tested for quality; again at the Department of Transportation Lab. Rock units were over-laid on the original topographic map, so that the feasibility of pit development could be evaluated. If the quality and volume of available rock were sufficient at an acceptable cost, a pit development plan was made again using the same topog map as a base. Overburden was also evaluated; what is the acceptable maximum stripping depth? Can overburden be handled and stored efficiently and safely? What are the environmental problems, i.e., streams, recreation site disruption, visual impact? Answers to these questions are relative to the availability of rock.

5. Overall Objective

The object was, and is, to identify rock sources that will yield large vulumes of quality rock at an acceptable cost, while disturbing the least amount of productive timber land. To avoid the "Quarry around every corner" problem, sites are finally selected on the basis of rock yield and area served. In the long-term this should minimize rock costs by:

1) Providing dependable, predictable rock sources.
2) Reducing development costs and land out of production by reducing the number of quarries.
3) Maintaining fewer total miles of road used for rock haul.
4) Providing rock of sufficient quality with better wearing characteristics, thereby reducing the volume of rock required for replacement.
5) Planning the use of poorer quality rock for ballast and one-shot spurs thus conserving the high quality rock for surfacing and high-volume roads.

We are developing a systematic approach to Rock Development that will be effective, efficient, and accurate for identifying potential quarries. The system should be repeatable, cost-effective and easily documented for future reference.

Accurate volume predictions pay off in another way, by keeping us from scheduling rock removal from an area that does not have rock. This is an extremely costly error that has been committed too frequently.

Cost saving resulting from professional exploration and documentation could be dramatic. The money we have spent has more than paid for itself. The Forest Engineer is providing a valuable service that could result in a 10:1 benefit to cost ratio as the system is refined.

CONSTRUCTION OF ENVIRONMENTALLY SOUND FOREST ROADS IN THE PACIFIC NORTHWEST[1]

Sandor A. Nagygyor[2]

Abstract: The "trench" method, in combination with endhauling to a safe disposal site is an accepted forest road construction technique. The method incorporates the old proven techniques with new ones that minimize soil erosion caused by road construction in the forest.

INTRODUCTION

The hazards to watershed values caused by forest road building and subsequent surface erosion were recognized early by forest managers and have commanded the attention of investigators since the early 1940s.

Road construction disrupts the basic equilibrium of steep-slope (over 65 percent or 33°) forest soils by altering slope drainage, slope loading (fig. 1), and slope undercutting. It has been identified as the greatest single cause of recent soil mass movements in the western states (Dyrness 1967, Swanston 1976).

During the 1964-65 Oregon floods which resulted from a 200+ year storm, 72 percent of the landslides on the Andrews Experimental Forest were associated with roads (Dyrness 1967), although roads occupied only about two percent of the area. The intensity of landslides was 315 times greater than that found in undisturbed portions of the forest (Fredricksen 1970).

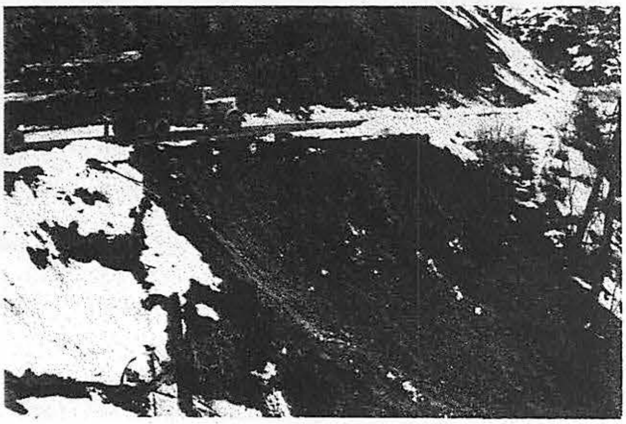

Figure 1.--Landslide caused by slope loading and side casting.

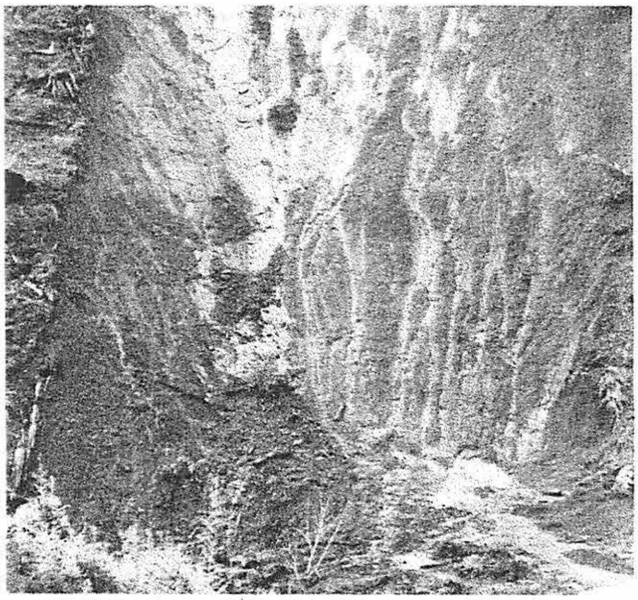

Figure 2.--Combination of translational - rotational slide caused by sidecasting and high pore water pressure.

Also in Oregon, a single road failure produced 40 percent of the total sediment yield for the year from a 303-hectares drainage containing 4 kilometers of roads constructed to permit clearcut logging of about 25 percent of the watershed (Brown & Krygier 1971). Similar results have been reported for forests elsewhere. In southern Idaho, 90 percent of the failures studied were associated with roads (Jensen & Cole 1965). In all these cases, roads had been constructed on steep slopes (fig. 2). These and similar findings have suggested that the forest manager minimize soil erosion and landslide risks by minimizing road mileage to the fullest extent possible, locating necessary roads on more stable portions of the landscape, and keeping road grades below 8 percent.

These methods, however, have been standard operating practice for road engineers. Attention has been focused on the more practical solutions of reduction of road width and endhaul of material to preselected safe disposal sites (Burroughs, Chalfant, Townsend 1973).

At present, however, almost none of the literature describes how these ideas can be implemented effectively in field conditions. That is why when these research findings were

[1]Paper presented at the conference COFE/IUFO - 1984. Orono, Maine, USA, 12-14 August.

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first presented, they were consistently rejected by forest managers, and little development of protective measures or construction techniques resulted. Managers' resistance came from: lack of understanding, rapid changes in woods labor and equipment that made some proposed techniques infeasible, and simply lack of economic incentives or "other motivations," such as strict rules and regulations.

By the early 70's, "other motivations" were strong enough to force most governmental agencies to develop new road construction methods previously not tried in forest management.

PROBLEM AND SOLUTION

When a road is constructed over stable ground, research and field observations have established that the causes of road-related landslides and/or siltations are:

1. Excess excavated material overloads the hillside, causing either sheet or rotational slides.

2. Excess material itself erodes away.

The apparent solution is simple: haul away all excess excavated material. On a 80 to 90 percent (38° - 42°) hillside, however, this is easier said than done. As engineers, our first step toward this solution was to determine a method which would contain the excavated material inside the right-of-way. We have devised the following steps to achieve such containment.

1. Directionally fall the right-of-way timber.

2. Eliminate clearing and grubbing of the right-of-way that typically occurs before the actual subgrade construction.

3. Start the excavation at the top slope stake.

4. Use the so-called 'trench method' to bring the cutslopes down to subgrade elevation.

5. Load and endhaul all excess excavated material to a safe disposal site.

Description of Work

1. Directional Falling

Directional falling of trees parallel to the centerline of the road is achieved by conventional falling methods, by use of tree jacks, or by pulling of trees. As the tree falls down parallel with the road centerline, it will roll against green trees or tree stumps and act as a temporary retaining wall. In western Oregon, generally, there are adequate numbers of trees in the right-of-way to do this.

2. Clearing and Grubbing

The elimination of the conventional clearing and grubbing has been easy since the contractor is happy to have one less chore to do.

3. Starting the Excavation

On hillsides 70 percent (35°) or over, the start of the excavation is the most critical step. To contain the excavated material, the excavation should begin at the upper slope stake (fig. 3). A small dozer, D7 or similar in size, can build a narrow pioneer road by drifting material against and on top of the fallen trees, logs and limbs. The logs and other woody debris act as a retaining wall so the initial excavation can be kept to a minimum. Usually, cuts two feet or less were adequate to construct a pioneer road 6-8 feet (1.8 - 2.4 m) wide (fig. 4). In this process, the use of the proper equipment is important because neither a Ford farm tractor or a TD25 can do the job. The right equipment will create a usable pioneer road without moving great amounts of material.

Figure 3.--Begin excavation at the upper slope stakes.

When rock is encountered, drifting dirt against or on top of the logs will form a temporary bridge to allow passage. The actual drilling and blasting will be done at a later time. I will explain the special blasting techniques in a moment.

The pioneer road can be constructed in segments, or to the full length of the road or progress simultaneously with the actual excavation.

Figure 4.--As excavated material is drifted on logs and other debris, it will form the pioneer road.

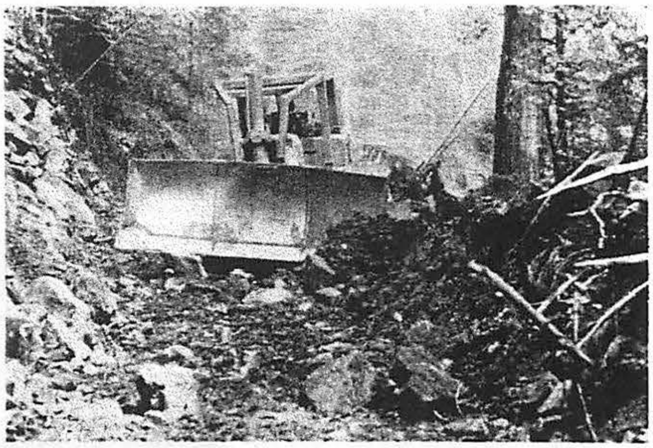

Figure 5.--Typical dozer excavation in the trench.

4. Using the "Trench Method"

To do the actual excavation, the trench system has proved to be a simple and effective method. The dozer should start about 30-40 feet (10-12 m) from the loader and work toward it. As the material is being drifted to the loader, the dozer will build a blade-wide trench. At first, some material will escape downhill, but logs and broken limbs will retain it inside the right-of-way. As the excavation gets deeper, the material from the outside wall of the trench will fall in front of the dozer and can easily be drifted towards the loader (fig. 5). As construction progresses, logs or other debris will be encountered. Debris can be either picked up with the excavated material or set-aside and hauled separately, depending on whether or not the excavated material is to be used for designed fills. If there is no designed fill, then only the usable logs need to be separated out. Broken tops and limbs can be buried in the waste area.

The trench method can also be used with the scraper. However, the pioneer road should be at least eight feet wide to give firm support for the scraper. Also, dozer help will be required to loosen the material to be excavated and to help the scraper to be loaded by pushing it. The excavation of common material by this method is fast and cost effective. However, most of the time solid rock slopes will be encountered, where the use of rock blasting is required.

Rock Blasting

Several excellent books have been written on rock blasting (Langefors & Kihlstrom 1978). However, for many years the art of rock blasting on logging road construction could be summed up in the phrase: "if we shoot it heavy enough then we do not have to move it again" (Teller 1980). Until the early 70's, such terms as presplitting, sequential blasting, subdrilling, detonation velocity, and blasting plan had no place in forest road construction operations. These sophisticated methods were the domain of freeway construction and quarry blasting. But, the use of "lifters" was common since on steep slopes it is the easiest and most economical method.

Most of the time ANFO (Ammonium Nitrate - Fuel Oil) was used since it has larger detonation pressure, and is cheaper than most other explosives (Teller 1980).

The first time controlled blasting was used in our forest operations, our motto was "the smaller the better". It worked beautifully. We drilled 3 foot (91 cm) deep holes on 3 foot (91 cm) centers and loaded them with ½ lb. (0.23 kg) explosive per cubic yard (0.76 m^3), and the rock stayed in place. But this was time consuming and expensive. Slowly, the depth of the drill holes has increased with our confidence and experience. The process was educational for all of us. It was easy to convert the contractor to controlled blasting after he had been overcharged several thousand dollars by a charge-happy driller who blew the whole hillside over the hill and down the creek. Presently, excellent jobs are being done by presplitting and by using properly arranged delays (Teller 1980).

In a successful blast, we will have all the rock stay in place or neatly piled against the temporary cribs -- not in the creek. The excavation of shot rock is not different than hauling common material. The trench excavation method was used again. We found that the most effective method is first to drift the shot rock to a loading area and then load it into trucks (fig. 6). Shot rock is not picked up by scrapers easily. I have seen $1500 scraper tires destroyed within a month by the sharp rocks.

Figure 6.--In the trench, a dozer could easily push the shot rock to the loading area.

This new system is easy and simple, but much advanced from old times when only a dozer was needed to push the excavated material over the side and down the hill.

5. Loading and Endhauling to a Safe Waste Area

Loading and endhauling of the excess material was never difficult, although it was and is expensive. Hauling can be done either by trucks or by dumpsters, depending on the equipment available or owned by the contractor, but not on economic considerations.

The major problem is finding a safe waste area where 10-20,000 c.y. (7,600-15,200 m^3) of material can be hauled. The location of safe, environmentally sound, waste areas was a new challenge not only for the engineer but also for the soil scientist. Due to remote locations and lack of access, we don't have the luxury of core soil sampling and the consequent stability calculations. We have had to rely on surface samples, but mostly on intuition.

CONCLUSIONS

During the past 10-15 years there have been great changes in road construction techniques and in the construction equipment used to achieve them. The system I have described is presently being used in combination with other newer techniques. The use of hydraulic excavators (Somere 1984), for example, is an accepted construction practice. At any rate, we have seen the end of the traditional type of road construction, with its distinct sequence of right-of-way falling, pioneer road construction, clearing and grubbing, and road prism excavation (Krueger 1983). Although attempts have been made to develop foolproof methods and formulas, our advancements are still essentially trial-and-error propositions. Everchanging geology continues to challenge not only engineers and contractors, but also equipment companies. We can envision even more innovative equipment, such as tractors, loaders and trucks which will travel on an air cushions, and allow road construction to proceed all year around without causing environmental damage.

I am sure all of us are up to this challenge and the time will come when our roads will not be blamed, rightly or wrongly, for every slide or muddy creek. We will have an acceptable product not for only ourselves but for the public.

LITERATURE CITED

Brown, G. W. 1972. The Alsea Watershed Study. Pac. Logging Congr., Portland, Oregon. Loggers Handbook 32:13-15, 127-130.

Brown, G. W., and J. T. Krygier. 1971. Clearcutting and Sediment Production in Oregon Coast Range. Water Resource Res. 7(5):1189-1198. Oregon State University, Corvallis, Oregon.

Burroughs, Chalfant, Townsend. 1973. Guide to Reduce Road Failures in Western Oregon. USDI Bureau of Land Management, Oregon State Office.

Dyrness, C. T. 1967. Mass Soil Movements in the H. J. Andrews Experimental Forest. PNW 42, Pacific Northwest Forest and Range Experimental Station, Corvallis, Oregon.

Fredricksen, R. L. 1970. Erosion and Sedimentation Following Road Construction and Timber Harvest on Unstable Soils in Three Small Western Oregon Watersheds. PNW 104, Pacific Northwest Forest and Range Experimental Station, Corvallis, Oregon.

Jensen, F., and G. F. Cole. 1965. Unpublished Report on File at the Payette National Forest. USDA Forest Service, Region 4, Idaho.

Krueger, C. B. 1983 (Unpublished). Road Construction in Critical Watershed. Report on File. USDI Bureau of Land Management, Eugene District, Eugene, Oregon.

Langefors, H., and B. Kihlstrom. 1978. Rock Blasting. Almquist & Wibsell Forlag AB Stockholm, Sweden.

Somere, Nick. 1984. Construction Techniques With Hydraulic Excavators. Forest Road Conference, Oregon State University, Corvallis, Oregon.

Swanston, D. N. 1976. Erosion Process and Control Methods in North America. XVI IUFRO World Congress Proceedings, USDA Forest Service, Corvallis, Oregon.

Teller, A. E. 1980. Techniques of Drilling and Blasting. Explosive Service Corp., Issaquah, Washington.

QUALITY IMPROVEMENTS IN WORK STUDY USING HANDHELD COMPUTERS

Jan Thorn Clausen[1]

Abstract.-- In the Nordic countries a joint project concerning developing better work study techniques has been going for 2 years. The project deals with handheld computers and their use in Forestry Research. Several computers have been tested in the harsh Nordic climate. Programs have been developed following a joint design criteria concept. Study quality and control has been improved by the use of computer technology. Several Nordic Forestry institutions now use a British computer, the Husky, as standard time study equipment.

BACKGROUND

The Danish Institute of Forest Technology, a nonprofit institution with the object of improving forest operations, was formed in 1967. In our R&D we use work study as a tool for analysing the various study objects. The Institute is very small (Danish Forestry is small-scale!), 10-12 persons organized in one-man departments (weed-control, machinary-consultancy, thinning operations, harvesting techniques, short-term management etc.).

When a work study is required, the project leader does all the nescessary work: planning, work study, punching and analysing data, transfer of the results in reports, papers and demonstrations. With this system you concentrate all the know-how in one person, who afterwards as a consultant is better suited to deal with all management levels (owners, administration and workers).

WORK STUDY HISTORY

Back in 1967 a very advanced work study board was constructed: 3 standard stopwatches placed in a row and activated as one. The stopwatches were initialized in the 3 different modes (running, stop and ready), so the time elements could easily be read from one of the clocks, while another measures the time of the next element. All data was written down on paper and later analysed. On fig. 1 the later development of our time study technique is shown.

1967 Birth of the Institute
- Study board with 3 stopwatches
- Manual analysis on desk calculator

1976 - Analysis on programmable calculator

1977 - TTY terminal for ONLINE analysis (SAS) on computer center via telephone

1978 - Electronic stopwatch

1980 - Data entry on local micro computer
- Transmission to computer center for analysis

1982 - Handheld computer for data collection
- Transmission direct to computer center for analysis

1984 - Computer center as intermediate database
- Retransmission to local micro computer
- Local analysis (SYSTAT)
- Bar code wand for data entry

Fig. 1. WORK STUDY HISTORY of Danish Institut of Forest Technology.

Analysis was done with the help of a normal calculator, summing rows and collumns and laborously making plottings on paper. In 1976 the summing was done on a programmable calculator, and this indicates our entry into the Electronic Age. A year later we bought a typewriter TTY terminal for ONLINE statistical analysis on a computer center via the telephone system. The punching of data was done by the timestudy personnel in order to avoid errors.
In 1978 we saw in a normal bookstore a cheap electronic stopwatch with a special lap function. Our fieldwork was now improved greatly by using one clock instead of three. The watch was later in use in Norway and Sweden, too.

In Scandinavia plus Finland we have govermentally financed joint projects. One of them deals with improvement of work study techniques in Forestry Research. One of the objects was to find improvements, which could be of common interest for all the Nordic countries. In 1980 a general Design Criteria for a handheld timestudy device and the software was developed. A systematic scanning of computer literature began.

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In 1982 we selected a British handheld computer, the HUSKY, which apparently met most of our demands. It was tested in all Nordic countries. A timestudy program for datacapture and -tranmission was developed and tested, too.

So the status now is that in Denmark and Sweden (and Norway soon) some Forestry institutions use computerized work study techniques all the way from the stump to the final report. I will in the following discuss the experiencies we have got so far.

DESIGN CRITERIA

SOFTWARE

Before getting into the 'Hardware Jungle' itself it is very important to specify precisely that you actually want the machines to do. That is a very classic and widely used remark, but difficult to follow. New machines are pouring onto the market almost every month - and they are always very interesting!

In Forestry Work Study dealing with R&D every study differs from one another with respect to lay-out, type, size, no. of elements etc. Some studies are continuous timestudies, some frequency studies. Some require extra variables measured during the study, such as diameter, lenght etc. Some consist only of numeric data (e.g. weed control studies). Work study programs must be able to handle all these study types.

Study Type
- Continuous time study
- GTT frequency study
- General data collection

Data Type:
- Time element + numeric variables
- One time element = One key
- Element code + time

Study Control:
- Dialogue system
- Informative messages

Data Transfer:
- "Handshaking"under program control

Study Evaluation:
- Print data
- Analysis of means
- Rough significance test

Fig. 2. Design Criteria of a work study program.

A point of practical importance is that the dialogue with and responses from the program must allow the studyman to be in complete control of the study. So statements as current observation number, name and time of last workelement and what the program expect from you next are important.

The work study program must handle the time-measurement in such a way that the time of the current workelement is recorded along with the total workcycle time. All times must be recorded in a decimal form e.g. decimal minutes.

Allocating a time with a workelement may be done in several ways. One way is first to type an element code and then record the time, when the workelement is finished. Another is to allocate keys directly to workelements, so you only have to press one key. With the first lay-out you have a very flexible system, where you may have as many workelements you like. The one-key system require a more or less fixed definition of the study lay-out. However it is more simple to operate, especially in a complicated study.

The recorded data should be transmitted to a host computer under program control, either directly or via modem/telephone or tape/floppy disk.

We also find it important to be able - inthe field - to do some preliminary analysis. A simple calculation of element and cycle means is very useful. We also include a calculation of standard error of mean in order to test the study size (no. of observations against standard deviation).

HARDWARE

The portable computer must be able to work in the Scandinavian winters with temperatures down to minus 20 °C (-4°F) and in daylong rain (nobody is interested in the studyman!). It should be shockproof and have a max. weight of 1 kg.

Environment
- Max 1 kg
- Waterproof
- Temperature down to -20° C (-4° F)
- Shockproof

Function
- Display min. 2 lines
- Keyboard "foolproof"
- Internal clock
- Large and safe memory
- Safe power supply

Flexibility
- User programmable
- Standard communication
- Variable communication parameters

Fig. 3. Design Criteria of physical device.

The display should contain at least 2 lines, preferable 4 or more. The keyboard should be workable with gloves, but also as 'hit-by-accident-proof' as possible. The power supply must be very safe and with a backup system. Operation must be garanteed for at least 10 hours.

The memory must be able to contain at least one full days study. How big it should be in K bytes is difficult to say (depends of the program), but probably min. 32 K RAM.

We find it very important that the work study computer can be programmed by the user himself. Many studies defer so much in organization that the research instititution will need to design program concepts easily and inexpensive. We also find that a standard communication capability is most flexible. No institutions in the Nordic countries use the same computer system.

STATE-OF-ART
The work in the Nordic project is concentrated on getting practical experiencies about 1) handheld computers and their function in the Nordic climate and 2) different types of programs including development and programming.

Fig. 4 HUSKY handheld computer.

In 1982 we bought a British computer, the HUSKY, which met most of our criterias. We developed a program package, HUSAS, which is able to perform both a continuous time study and general data collection - but at the moment no frequency studies. The machine and program was tested at all Nordic Forest Work Study institutions. The HUSKY computer and the HUSAS package is now the standard work study equipment at the Danish institute.

We found quickly that the main problem with the Husky computers is the Nordic winter. At temperatures below -5^{o} C Husky works clearly slower and not at all below 10-15^{o}C. The computer itself is very useful and flexible, so we have tried several heating systems. The one that worked needed several kilos of battery power!

Computer
- Husky (64-144 K RAM)
- Husky Hunter (80-208 K RAM)

Design
- Standard Timestudy with 10 time elements + 5 numeric elements
- Element allocated keys (element+time=1 key)
- One cycle = one line with 15 variables
- General datacollection of up to 15 variables per observation

Analysis
- Print hardcopy/display
- Element means
- Cycle mean + standard error of mean

Data Transmission
- "Handshaking" with computer center
- Direct input in any host computer

Fig. 5. HUSAS Work Study System.

Recently we got in contact with the Norwegian Defence Research Institute, who has developed small, portable heating systems in order to keep wounded soldiers warm in arctic areas. The heat is provided from small charcoal burners, which produce a stream of hot air. In combination with the handheld computer stowed in an insulated bag and the input controlled by a bar code wand, we hope to have solved the crucial temperature problem.

The Nordic project also tested some other handheld computers and work study programs, mostly Swedish systems. The programs are based on the principle: element code + time measurement (2 to 3 keys). The computers (e.g. DATADON and MICRONIC) meet the climate criterias, but are more inflexible with respect to user programmability and communication.

STATUS

After about two years of practical use of handheld computers we have found both improvements and drawbacks. The system really cuts time handling the data. Errors are also reduced significantly. With a well planned study 50-80 % of the analysis can be done just after the study (Analysis of means). Off-days as rain and snow are used more efficiently with statistical analysis.

IMPROVEMENTS:

Timesaving
- No punching of data
- Analysis of means => 50-80% of total analysis
- Statistical analysis on "off-days"

Study Evaluation
- Standard Error of Mean => cuts fieldwork time
- Analysis of Means => involves study object more

General

- Improved observation of study object =>
  - = Better practical conclusions
  - = Complicated studies more simpel to perform

DRAWBACKS

- Studymen refuse to use "oldfashined" clocks
- Telephone connections must be "noise-free"

Fig. 6. Work Study Status 1984

We have found that the studyman has his eyes almost all the time on the object, because he only has to press one key to register the time element. More detailed practical information of the e.g. work method is collected in that way.

Earlier with the old technique the result of a time study was a pile of paper - sometimes wet and almost unreadeble. During a study the forest worker or tractor driver gets very interested in the study and a professional discussion often starts. But he is normally disapointed, because the studyman knows nothing of the result. With the computer you can read intermeadiate results out after each break - and the discussion at once starts at a high level - to the benefit of both.

Of course we have found some drawbacks. We have now no arguments against a study on a tractor in daylong rain, where the data and the driver are warm and safe indoor!
It is also very hard to get studymen to work with 'oldfashioned' equipment such as electronic stopwatches!
In the beginning we had strange disturbances during transmission via telephone to computer center. We used the normal telephone in the hotelroom, and it has a counter connected, which said 'beep' once a while - and our computers didn't understand that!

Talking seriously, the drawbacks are not of any importance. Our investment in handheld computers is generally a story of happiness.

FOREST WORK STUDY TECHNIQUES - A SURVEY OF CURRENT METHODS[1]

Benjamin F. Hoffman[2] and Morgan L. Cameron[3]

Abstract.--A survey of persons and organizations involved in forest work study revealed that most such work still relies on the conventional observer with stopwatch and clipboard, and Servis recorders. Most data are transferred to computing equipment manually. New developments include videotape and a variety of portable electronic data recording and storage devices capable of automatic transfer to computers. Most new devices are custom-built for research use. A tabulation of the results and a discussion of equipment is included.

INTRODUCTION

The collection, storage and retrieval of forest work study data is expensive and subject to several problems specific to the forest environment and the nature of forestry operations. Unlike other industrial operations, a single forestry operation, such as skidding, may cover a mile-square area of variable topography. Collecting data from the stump and landing, which may be half a mile apart, presents unique problems. In addition to the physical aspects of the operation, variables such as temperature, precipitation, insects and ground cover add to the complexity of such studies.

Further, the automation of data collection requires electrical power, which in turn necessitates portable power supplies. If the recording equipment and power source are to be carried by men, they must be small in size, light in weight and relatively immune to damage by dropping. If mounted on a woods machine, small size is desirable, and equipment must withstand constant vibration and frequent severe jolting.

For years, an observer with stopwatches mounted on a three-watch clipboard has been the standard in forestry work study data collection. Supplementary machine performance data have been obtained with automatic sensing and recording devices mounted on the machinery. In some ergonomic studies, workers have been equipped with devices to measure and record vital physiological data. In the past, most such information was manually entered into data processing machines.

Recent improvements in electronic technology have produced portable handheld microprocessors suitable for data entry in the field. Some units include timing functions so that time study data can also be recorded and retrieved. In most instances, information collected by electronic means can be automatically transmitted from the data logging device to a processing unit in the office or laboratory. With some devices data can be transmitted to a central computer by telephone modem at the end of the work day, and the completed analysis is on the desk the following morning.

Photography, both still and motion picture, is being supplemented or replaced by videotape, as picture quality can be verified on site to insure that it is adequate for later analysis.

In order to evaluate the changes taking place in forestry work study, the International Union of Forestry Research Organizations (IUFRO), Division 3, Forest Operations and Techniques, Working Party on Production, Labor and Wages (S3:04:02) planned a study in 1982 to ascertain recent changes and new developments in the collection, recording, storage and retrieval of work study data. In January of 1983, a survey was conducted to determine the "state of the art" in forest work studies.

METHOD OF STUDY

In January 1983, 210 questionnaires were mailed to persons and organizations known to have been involved in work study. As the mailing list was compiled from several different sources and was by no means complete, a statistical analysis of the results was not intended. In many cases, two or more persons in the same organization were questioned, and more than one person often replied. In those cases where the respondent might not be actively engaged in such work, he was asked to provide names and addresses of others who might be involved.

The results of this study would be useful only in determining the methods currently in use,

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[1]Paper presented at the COFE/IUFRO-1984 conference, Orono, Maine, USA, 12-14 August.

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without any definition of which were most popular. The questionnaire sought to determine:

1) How work is measured - methods for recording, storing and retrieving data.

2) The type of hardware used for measurement and analysis.

Figure 1 shows the questions which were posed.

WORK MEASURED:

How is the data recorded?
Investigator in field -
Equipment operator -
Automatic machine recorder (mechanical, electronic) -
Other?

How is the data stored?
Data sheets -
Electronic memory -
Magnetic tape -
Other?

Additional Comments?

HARDWARE:

Type of equipment used for recording data?
('Servis' recorder, stopwatch, etc.)

Type of equipment used for data analysis?
Handheld calculator -
Microprocessor -
Mainframe computer -
Other?

New design?

After two months, a tabulation of responses was prepared to show what methods are in use, with some indication of their frequency of use.

RESULTS

The survey was sent to 79 persons in 19 foreign countries, of whom 32, representing 12 countries, replied. Of the 131 forms sent within the United States, 56 were completed and returned. From the total of 88 responses, 32 persons were no longer involved in work study or did not provide useful information. Multiple responses were often returned from one organization, compiled into one response representing that organization. The basis for the results is therefore 56 persons and organizations which are actively engaged in work study of forest operations.

Work measurement concerned the methods of data collection, recording, storage and retrieval. Recording was accomplished by three principal means, the investigator, the operator or automatically by electrical or mechanical recorders (see Table 1). Many investigators used more than one method or a combination of several.

Table 1. Methods of work study data recording, by number of responses.

Investigator	Machine Operator	Automatic Recorder	Other Film or Videotape
31	8	17	6

Data were stored in several forms, but chiefly on conventional field data sheets, as shown in Table 2.

Table 2. Methods of work study data storage, by number of responses.

Data Forms	Electronic Memory	Magnetic Tape	Other: Film or Videotape	Other: Recorder Disks	Other: Computer Copy/Disks
43	18	12	8	13	3

As in the case of recording, some individuals used more than one of the above methods, or a combination, to store data.

Most respondents still performed data retrieval in the traditional manner - keypunching or otherwise manually entering directly into a computing device from field study sheets. Forty-four respondents used manual transfer, but 14 read data directly from magnetic tape or disks into the central processing equipment. Some data logging devices are capable of direct connection to computers or can have data transferred by telephone modem.

With regard to "hardware" in current use, the traditional stopwatches and board - conventional or digital - are still widely used, as is the Servis recorder. Motion pictures are also in use but video-cameras are being used increasingly. Tape recorders and portable electronic recording devices are also used, but in small numbers. Table 3 outlines the frequency of use found through the survey.

Table 3. Hardware used for the conduct of forest work studies, by number of responses.

Stopwatch and Board	Servis Recorder	Film or Videotape	Tape Recorder	Portable Micro-processors	Electronic Data Logs
38	16	10	1	8	5

Most respondents used several types of hardware, but there was a general absence of applications of small electronic devices to work study in the forest. Many of the electronic devices in use were custom made for the user. However, in the area of data analysis, most investigators are using modern computers, as outlined in Table 4.

Table 4. Type of equipment used for data analysis, by number of responses.

Mainframe computer	Micro-processor	Handheld calculator
37	25	26

DISCUSSION

The limited use of portable electronic data collection devices in forest work study is not really surprising. Most new developments in this field have been custom built, prototype units designed and fabricated for research work by organizations such as the Forest Engineering Research Institute of Canada (FERIC) and the Finnish State Research Center. The cost of such units makes them impractical for most industrial applications, but intensive and detailed research studies can often justify the cost.

For many industrial studies, traditional stopwatches and recorders produce adequate data for cost and production analysis. Here, the measurement of work elements within the nearest five seconds is adequate. However, for equipment design studies, greater precision in time measurement is required. For example, the felling cycle of a feller-buncher, normally a single work element for costing and production analysis, might be subdivided into several subelements. Many of these subelements of high-speed machine operation are too rapid for accurate manual recording. In cases such as these, automated data collection using electronic sensors, high-speed cameras and other sophisticated devices might be required.

As an example of the more advanced equipment in use, data-logging devices designed and built at two universities permit multiple, simultaneous, continuous monitoring of up to 16 events. The University of British Columbia developed a recorder for monitoring cable logging operations (Lawrence et al. 1982). Operation requires the yarder operator to insert a new cassette tape and recharged battery at the beginning of the day and turn the system on. The process is reversed at night. The University of Saskatchewan custom-built a 16-event recorder for FERIC (Heidersdorf 1983) which has been used for detailed recording of feller-buncher activity. Research scientists have developed and used some of these more sophisticated combinations of data collection and processing systems because much of the technology and expertise is readily available to them.

Videotaping is increasingly used for data collection, using both the video and sound systems for recording. Not only can elapsed time be read from the videotape, but the physical dimensions of the machinery and the number of pieces, size and quality of forest products can be measured from the image using a technique called videogrammetry (Cameron 1984).

Transfer of field data from tally sheets and recorder discs to computing equipment has been a tedious, manual task in the past, and a source of error. Portable data logging devices with time functions are now commercially available in Great Britain, Sweden, West Germany and the United States, at costs of $1,000 or more. By 1984, portable microprocessors were available at prices as low as $1,500 (Clausen 1984). In addition, for recording and analyzing site data which do not require time measurement, a variety of recording devices designed for agricultural and forestry use are also available. With such recorders, as well as with tape and video recorders, information can be transferred to data processing equipment by direct wire or telephone modem. In one instance, Servis recorder graphs were read into the computer using a digitizer.

CONCLUSIONS

Currently, the use of sophisticated electronic data logging and processing equipment for forest work study is largely limited to research studies.

Because of the cost considerations and the limited demand for specialized tools for industrial forest work studies, it is unlikely that such equipment will be widely adopted in the near future. As other applications of this technology take place, resulting in a wider variety of equipment, and lower prices, more general use can be anticipated. In the meantime, it is likely that highly specialized equipment development and use will be limited to intensive research into new machine designs and ergonomic studies where a high degree of precision is required.

LITERATURE CITED

Cameron, M. L. 1984. Development of a computer and photogrammetric measurement system for machine time/production evaluation from video imagery. Unpublished M.S. thesis. College of Forest Resources, University of Maine at Orono. 55pp.

Clausen, J. T. 1984. Personal communication.

Heidersdorf, E. 1983. Personal communication.

Lawrence, P. D., P. L. Cottell and B. J. Sauder. 1982. Programmed data logging in forest harvesting using floating-aperture data compression. IEEE Transactions for Instrumentation and Measurement, Vol. IM-31, No. 2, pp. 132-137.

TOTAL TREE CHUNKWOOD AS RAW MATERIAL FOR FLAKE PRODUCTS[1]

Bruce A. Haataja, Roy D. Adams and Rodger A. Arola[2]

Abstract. This study evaluated the technical and economic suitability of flakes made from chunked aspen and soft maple wood produced by the Forest Service "chunking machine" as furnish for flakeboard, oriented strandboard and highly aligned products. Results indicated that structural panels can be produced with acceptable strength and physical properties. Analysis indicated that net raw material cost savings are possible with the chunkwood system.

INTRODUCTION

Structural flakeboards rely on engineered, high quality, bark free flakes in developing their superior strength properties at low resin levels and medium densities. This is true for both random and oriented strandboards. For the most part, the flakes for these products are made from peeled logs or pulpwood bolts. The logs are directly converted with disk, drum or lathe type flakers to produce the quality of flakes needed.

An alternate system for producing flakes is from forest residue and total tree material, which recovers 1.5 to 2 times as much wood per acre as conventional logging. Total tree harvesting is becoming more prevalent as a system for recovering wood for fuel, pulp and paper, fiberboard and particleboard. Forest residue and total tree material may be converted to flakes by first reducing it to chunks (chips that are 2 to 4½ inches long), processing the chunks into fingerlings (particles that are 2 to 4½ inches long by about 3/4 inches in cross-section) and then flaking in a ring flaker (6).

The key element in this process has been the system for producing the fingerling of proper geometry. Researchers (4,5,7) have reported that high quality flakes could be made from total tree material in a ring-type flaker if the material were first reduced to a fingerling size particle. In general, these researchers have noted that while disk flakes produce panels with improved properties, ring-flaked panels can exceed Canadian and American Standards. In 1972 Heebink (8) presented a challenge to the designers of chipping equipment to develop a machine to produce fingerlings.

The size and geometry of fingerlings are important for several reasons. The length of the fingerling controls the upper limit of flake length. It is necessary that flake length be substantially 2 inches or greater for structural flakeboard, therefore the fingerling should be 2 inches or greater in length. Since ring flakes rely on centrifugal forces to position the fingerling's long dimension parallel to the cutting edge of the knife, the fingerling should have about a 4 to 1 length to thickness ratio to insure a proper positioning with the knife. Fingerlings that are long enough but too thick in cross-section do not feed well through a ring flaker without plugging the machine. Further, the cross-section of the fingerling controls flake width. For oriented strandboard it is important to have long narrow strands rather than wide wafers.

The studies referred to indicate the need for equipment to produce a high quality fingerling. In addition to the drum chipper used by Heebink et al., other machines have been developed to produce large chips and fingerlings. Erickson (4) reported on a spiral-head chipper developed by the U.S. Forest Service, Forest Science Laboratory at Houghton, Michigan. This machine produced chips or blocks about 2½ inches long. The chips, when fed through a hammermill, broke down into fingerlings. Panels made from these ring flaked fingerlings had good properties. Recently, the Forest Science Laboratory at Houghton has developed a chunking machine reported by Arola et al., (1) which produces chunks from 2 to 4½ inches long with cross-sections often equalling the entire tree cross-section. Usually the chunk has longitudinal fractures which help in the subsequent breakdown of the chunk into fingerlings. The Institute of Wood Research at Houghton developed a prototype chunk splitting machine which is capable of reducing chunks into fingerlings while retaining the original chunk length. With these two machines, fingerlings 2 to 4½ inches in length by approximately 3/4-inch cross-section were produced.

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[1]Paper presented at the Symposium of the Council on Forest Engineering and International Union of Forestry Research Organizations - 1984. Orono, Maine, USA, August 13.

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A technology for producing a high strength composite wood material (CWM) from elongated wood flakes has been developed at the Institute of Wood Research. Structural products, such as utility poles and crossarms, have been manufactured from CWM and are undergoing service testing. The CWM technology currently uses species which would not usually be found as structural products. Although this material requires an engineered flake, i.e., size is restricted to fairly close tolerances, it is anticipated that these flakes could be produced from small trees and residue material, providing that suitable production equipment is available.

Under contract with the USFS, the Institute of Wood Research conducted two research studies involving chunkwood. The objectives of the studies were to evaluate the technical and economic suitability of flakes produced from chunkwood as furnish for flakeboard products. A particular objective of the second study was to determine the way in which board density and strength properties were affected by combining dense hardwood and aspen flakes.

The purpose of this paper is to describe the laboratory methods and equipment used to process bolts into high quality flakes using the chunkwood concept and to relate this to a commercial situation. A flow diagram outlining project steps is shown in Figure 1.

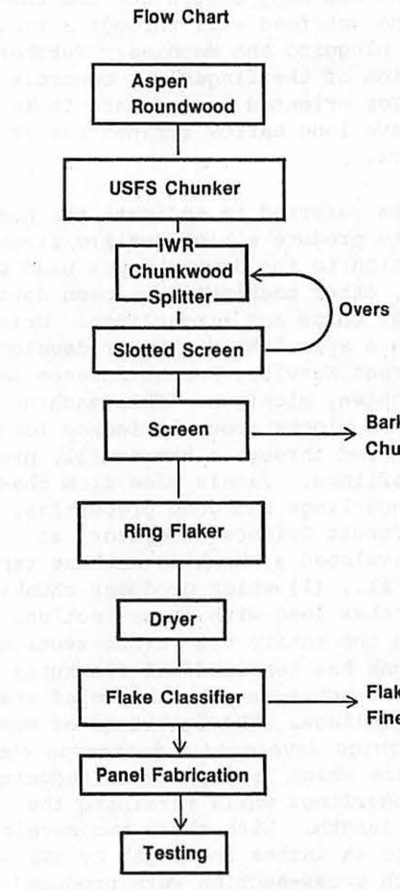

Figure 1.--Flow Diagram for Project

MACHINE DESCRIPTIONS

USFS Chunker

The USFS wood chunker was specifically designed for controlled laboratory testing to reduce roundwood bolts up to about 9 inches in diameter into chunks (Fig. 2). The flywheel and carrier for the cutting blades was a 1-3/4-inch-thick, 3-foot-diameter steel disk. The disk was mounted on a horizontal shaft running in a pair of bearings secured to a rigid frame. A diagram of the chunker is shown in Figure 3.

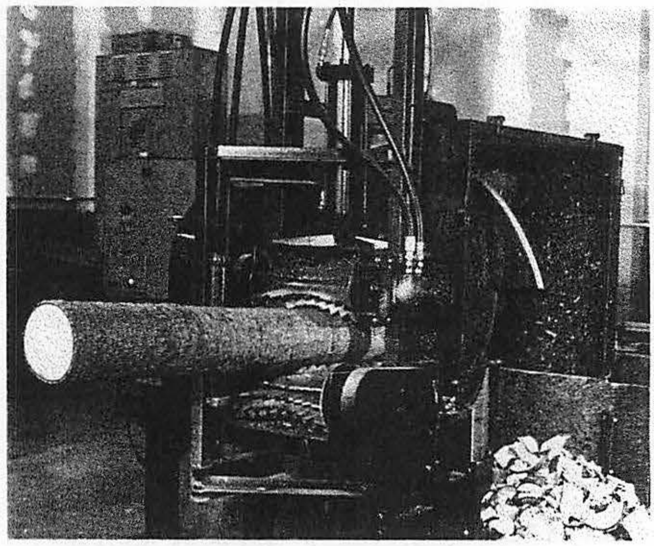

Figure 2.--USFS Chunker

Three curved, 24-inch-long, detechable blades, bent on an 18-inch radius, were mounted 120 degrees apart and positioned on the face of the disk so that the curved plane was at right angles to the axis of the workpiece. The leading edge of each blade was set at a greater radial distance from the center of shafting than the trailing edge. The blades were tapered so that the leading edge projected about 1 inch from the face of the disk, whereas the trailing edge projected about 9 inches (equivalent to the maximum diameter of cut). Two sets of blades for testing were fabricated - 1/4 inch and 3/8 inch thick - both with a 30 degree included angle double bevel.

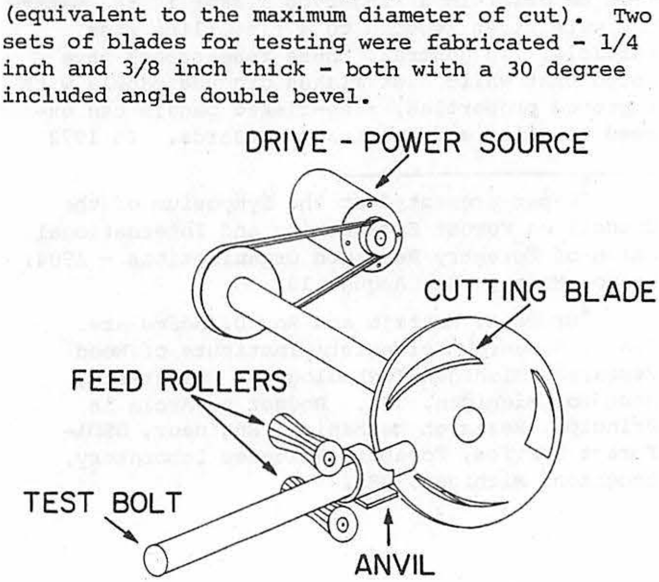

Figure 3.--Diagram of USFS Chunker

The workpiece was fed through a tubular anvil made from a 9.5-inch-diameter pipe horizontally secured to the infeed frame. The anvil tube was located near the rim of the disk, but offset from the plane of the disk, to match up with the cutting blades. The center of the anvil tube was positioned slightly below the disk center to obtain the desired entry and exit of the blades. The anvil tube was contoured to provide slight clearance between it and the blades as the chunks are severed from the workpiece.

Because the workpiece does not self-feed, a pair of hydraulically powered rollers was positioned immediately ahead of the anvil. The speed of the feed rolls was adjustable. To accommodate test bolts of different diameters, an air-operated cylinder was used to lift the upper roll to insert the bolt and to exert a downward force on the workpiece during test.

A 175-horsepower diesel engine provided power to operate the chunking machine. The disk was driven through a speed reducer and sprocket/roller chain drive system. The rotational speed of the cutter disk is variable.

IWR Chunkwood Splitter

When long wood chunks (i.e. 2-4" long) are produced, they usually have large transverse sections and may be as large as the cross section of the tree stem being chunked. Usually some longitudinal splitting occurs, but chips remain large enough in cross-section to cause flow problems through a ring flaker. Large cross-section chips also produce wider flakes than what is desired for flake alignment processes. Wide flakes can be reduced in width by subsequent operations but generally at the expense of additional "fines".

The IWR chunkwood splitter is based on a concept for splitting large chunks into fingerlings without producing an excessive amount of "fines" or damaging the chunks in ways which would produce excessive fines in subsequent flaking. The basic tool or bit employed by this concept is a hardened steel cone with a relatively sharp point. Splitting is caused by impaling the chunk with the cone shaped bit. The chunk may be pierced at any possible grain orientation. This will cause splitting along the grain. With a sharp point on the bit no cutting and little crushing of the wood fiber occurs.

While several machine designs are possible the IWR laboratory model chunk splitting machine was made using a jaw mounted with impaling bits. Figure 4 shows a sketch of the arrangement of jaw mounted with impaling bits, cleaner plate and bedplate. A photograph of the laboratory machine is shown in Figure 5. The features of of this machine include the following:

1. A hinged impaling head so that it works like a jaw with the bedplate.
2. A cleaner plate is included so that any chips that stick to the impalers are wiped off when the head rises.
3. A hydraulic cylinder which actuates the impaling head.
4. More numerous and smaller diameter impalers further into the throat of the machine to provide increasing chances of additional splitting as the chips move through the machine.
5. Impalers of simple configuration.
6. A sloped bedplate to allow gravity flow of material through the machine.
7. A gate at the lower end of the bedplate (not shown) which controls the flow through the machine when the jaws are open.

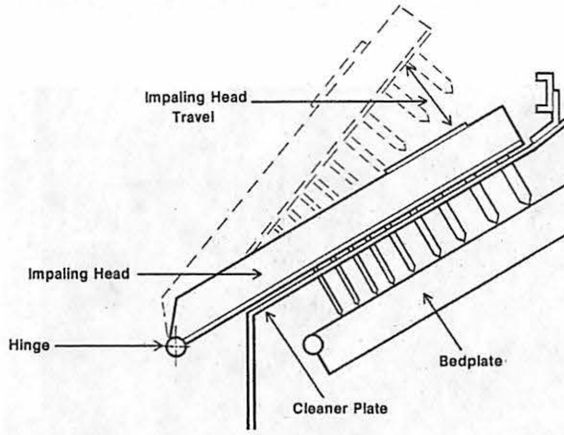

Figure 4. Section View of Impaling Head, Bedplate and Cleaner Plate.

This laboratory chip splitting machine successfully reduced large wood chunks produced by the USFS wood chunker into fingerlings that passed through a 3/4-inch slotted screen.

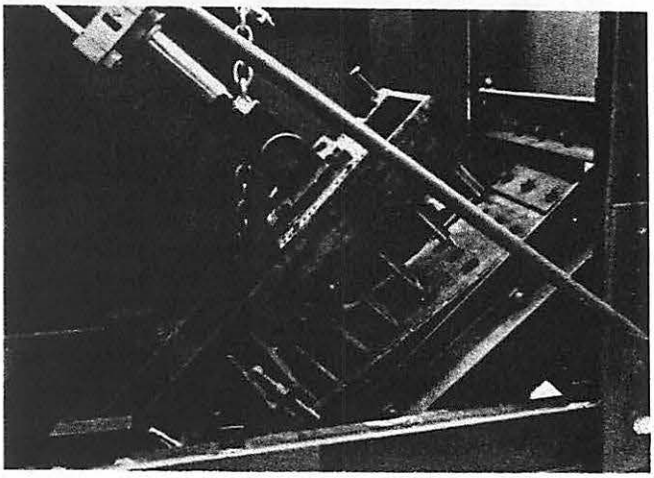

Figure 5.--IWR Chunkwood Splitter

FLAKE AND PANEL PRODUCTION

General Observations

Log quality was limited to sound logs and size to maximum capacity of the "chunking machine", i.e., approximately 8.5 inches in diameter. Sample bolts were reduced to 2 to 4-inch long chunks on the Forest Service's chunking machine. The aspen chunks shown in Figure 6 were too large for ring flaking and were subsequently reduced to fingerlings of 3/4-inch cross-section in the prototype chunk wood splitter. A 3/4-inch rotary slotted screen was used to accept only those particles meeting the required cross-section. All oversize material was recycled through the chunkwood splitter until acceptable in size. Figure 6 also shows some typical aspen fingerlings.

Figure 6.--Aspen Chunks Produced by the Forest Service Involuted Disc Chunking Machine, Fingerlings That Were Split From Chunks in the Institute of Wood Research Prototype Chunkwood Splitter and Ring Flakes Made From the Fingerlings.

The accepted fingerlings were flaked using a Black Clawson MKZ-14 ring flaker at the Institute of Wood Research. The flaker knives were set to produce a nominal flake thickness of 0.020 inches, and a sample of fifty flakes randomly selected, averaged 0.020 inches in thickness. The length of the flakes were determined by the length of fingerlings which ranged from 2 to 4½ inches long. Example flakes are also shown in Figure 6. The flakes were dried to 5 percent moisture content. Three flake classifications were then obtained, i.e., those retained by 1/8, 1/4 and 1/2-inch screens, referred to as +1/8, +1/4 and +1/2, respectively. These screen sizes approximately determine the minimum flake width retained.

Study No. 1

Sixteen panels 1/2 x 16 x 96 inches were fabricated at a nominal density of 42 pounds per cubic foot (pcf). Typical panels are shown in Figure 7 with a close up of a highly aligned (CWM) panel in Figure 8. Panel differences were based on flake classification and adhesive type/level. The adhesive type/level was related to the flake orientation method used. A 5 percent level of phenol-formaldehyde was used for random and oriented strandboard panels and an 8 percent level of isocyanate used in the highly aligned panels. The resin and flake classification choices were based on those used in commercial and experimental panels whose strength data can be used for comparison. The press temperature was 330°F and press closing was achieved in one to two minutes. The press time for the phenol-formaldehyde adhesive was 20 minutes and 15 minutes for isocyanate adhesive.

Study No. 2

In this work a dense hardwood species-soft maple (*Acer rubrum*)- was selected to be combined with aspen in the production of panels. Soft maple was chosen since it is overabundant in the Lake States, often has poor form on "off" sites and is frequently unsuited for sawmilling, and grows thickly on good sites allowing substantial thinning volume. Also, its texture and density are similar to paper birch (*Betula papryifera*) suggesting that similar results might be achieved with paper birch.

For Study No. 2, ring flakes were produced from chunkwood manufactured from aspen and soft maple bolts in the same manner as Study No. 1. The flakes used for test panel production were those retained on a 1/4-inch screen. Ninety panels 1/2 x 18 x 18 inches were fabricated at a target density of 42 pcf. As in Study No. 1, all random and oriented strandboard panels were blended with 5 percent liquid phenol resin. The highly aligned material was blended with 8 percent isocyanate adhesive. Other than board type, variables included the ratio of aspen to soft maple flakes and homogeneous mixtures vs. layering. Layering was accomplished by using one half of the total aspen component for a particular panel on each surface and soft maple was used for the cores. The press temperature was 350°F and press closing was achieved in one to two minutes. The press time was 12 minutes.

PANEL PROPERTIES AND DISCUSSION

Average values for bending strength (MOR), bending stiffness (MOE), material density and internal bond (IB) are given in Table 1 for the two studies. Data are given for random oriented panels, oriented strandboard (OSB) and highly aligned material (HAM); in addition minimum values required by Commercial Standard CS 236-66, (13), Forest Service Targets (4,12) and data from a study by Price (12) are presented. The MOR and MOE averages for the aligned material (i.e., OSB and HAM) are given parallel to the flake orientation.

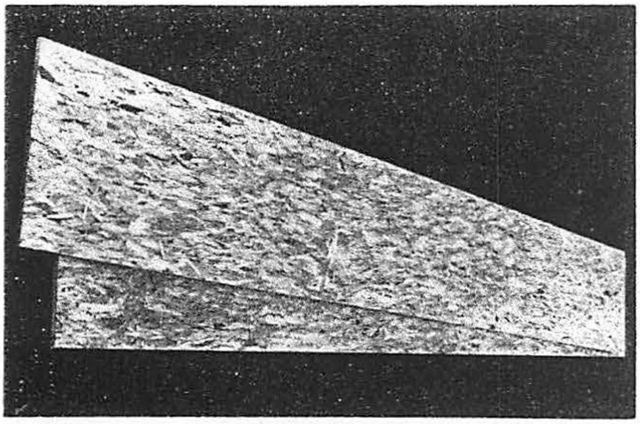

Figure 7.--Typical 1/2 x 16 x 96 Inch Panels Made From Chunked Wood.

As one would expect material density influences strength. Regression analyses were performed using the individual data points and we found that as the panel properties increased the density effects became more marked, so that a change in density of the highly aligned material has far more influence on properties than for the random panels.

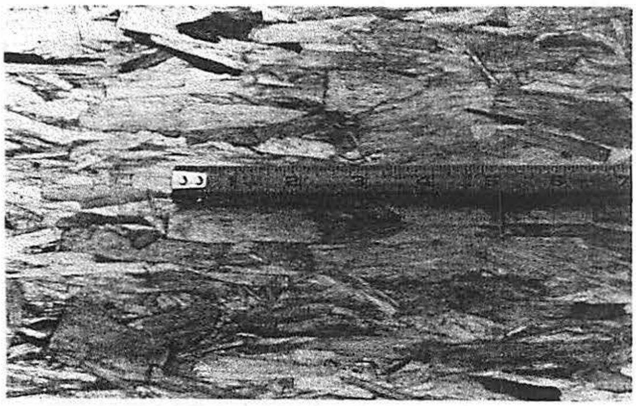

Figure 8.--A Close Up of a Highly Aligned (CWM) Panel.

The results of the two studies were comparable even though combinations of aspen and soft maple were used in Study No. 2. Data for the 50:50 mix are presented. In Study No. 2 the various aspen to soft maple ratios and homogeneous versus layered panel configuration appeared to have little effect on bending characteristics. The influence of flake classification in Study No. 1 was minimal and inconsistent therefore results are combined in the average values presented. The effect of flake orientation on bending properties is seen when comparing the random and OSB panels which were made with the same liquid phenol-formaldehyde adhesive levels. The use of higher levels of isocyanate adhesive and a greater degree of orientation is seen in the high bending strength results for the highly aligned material.

Table 1. Comparison of Test Results, Commercial Standard, Target Values, and Published Flakeboard Properties

TABLE 1

COMPARISON OF TEST RESULTS, COMMERCIAL STANDARD, TARGET VALUES, AND PUBLISHED FLAKEBOARD PROPERTIES

SOURCE	PROPERTY			
	MODULUS OF RUPTURE (PSI)	MODULUS OF ELASTICITY (PSI x 10^3)	DENSITY (PCF)	INTERNAL BOND (PSI)
Test Results				
Study No. 1				
Random Panels	4265	705	41.9	43.0
OSB-Aspen	8145	1365	45.9	78.3
HAM-Aspen	11680	1810	41.0	221.2
Study No. 2				
Random Panels	5605	730	44.8	81.4
OSB-50:50 Aspen/Maple Mix	7610	1195	40.9	65.6
HAM-All Mixes	12737	1770	42.3	301.8
Commercial Standard CS 236-66	2500	450	37 to 50	60
Forest Service Targets	4500	800	37 to 43	70
Published Study				
Random Panels	5300	800	47.5	83
Oriented Panels	6600	1090	45.5	82

The purpose of Commercial Standard CS 236-66 is to establish a voluntary standard of quality for particleboard and is intended to provide minimum property values. Those listed are for medium density material bonded with a durable adhesive and therefore suitable for certain exterior applications. The Forest Service Target values shown were developed for flakeboard, so that flakeboards meeting these goals should perform satisfactorily in structural applications.

Observation of the bending strength values in the two studies involving material made from ring flakes indicates properties much greater than the minimums given in CS-236. Except for the random panels in Study No. 1, MOR values exceed the Forest Service targets and results achieved by Price (12) using hardwood mixtures. MOE values of random panels were somewhat lower but manipulation of density and/or manufacturing techniques could increase the results.

The effect of the fairly high levels of isocyanate adhesive on internal bond strength can be seen in Table 1 which shows very high values for the highly aligned material. Internal bond values using the phenol-formaldehyde were low, however in most cases they approached or exceeded the values in CS-236 and the Forest Service target values. Again manipulation of density and production techniques should improve these values.

The results presented indicate that it is feasible to produce structural panels using ring flakes obtained from chunked wood using either aspen or aspen:soft maple combinations. Although strength properties of the highly aligned material were somewhat lower than those recorded for material produced from drum-type flakes the bending strength properties were exceptional and thus material produced from ring flakes has application in the IWR composite wood products.

Other hardwood species of the Lake States should be considered for furnish for composite products. Based on the results of this study, it is likely that paper birch and American elm could be substituted for soft maple because of density similarities. Other hardwoods such as red oak, hard maple, yellow birch and American beech are also potential species. Substantial volumes of all of these species are available in chunkable form, such as small diameter low grade trees, logging residue and thinnings.

PRELIMINARY COST COMPARISON

Estimates were made of the cost of producing flakes from roundwood and from chunks. These are shown in Tables 2 and 3 which indicate the cost of producing one ton (oven-dry basis) of +1/4 and +1/8-inch classification flakes from each system, respectively. Since fewer trees are needed to produce a given quantity of flakes from chunks than roundwood the cost of stumpage and harvesting wood for chunking is less. Also, the procurement radius for chunks would be less than for roundwood resulting in lower trucking costs.

The net cost differences are dependent on the classification of flakes desired after screening. The chunkwood system recovers the greatest volume of wood from each tree and the roundwood system recovers the most from the material actually brought to the mill when a +1/4-inch flake classification is sought. This balances out some of the previously mentioned gains from the chunkwood system and leaves it with a small cost advantage. However, if a +1/8-inch flake classification is used then the recovery from chunkwood improves so that the system has a cost advantage of about $24.05 per ton. Figures 9 and 10 illustrate material balances for +1/8-inch flake classifications. Should stumpage rates be increased to $15.00 per cord, as they are for some species in certain areas, then the +1/4-inch and +1/8-inch chunkwood systems would have $15.24 and $30.34 per ton advantages, respectively.

Table 2. Cost of Producing Roundwood Flakes From 1 Ton of Standing Timber (O.D. Basis)

1.	Stumpage - 0.57 cords (1 ton) @ 5.00	$ 2.85
2.	Procurement Fee - 0.57 cords @ 2.50	1.43
3.	Harvesting - 0.57 cords @ 19.00	10.83
4.	Haul - 0.57 cords @ 15.00 (50 miles)	8.55
5.	Yard - 0.57 cords @ 5.00	2.85
6.	Thaw - 0.57 cords @ 4.33	2.47
7.	Debark - 0.57 cords @ 12.00	6.84
8.	Flake - 0.485 @ 9.51	4.61
9.	Dry - 0.485 @ 17.76	8.61
10.	Classify - 0.485 @ 1.06	.51
	Total	$ 49.55

Cost per ton of +1/4 inch classification flakes

$= \frac{\$49.55}{.403 \text{ tons}} = \$122.95$

Cost per ton of +1/8 inch classification flakes

$= \frac{\$49.55}{.415 \text{ tons}} = \$119.40$

Table 3. Cost of Producing Ring Flakes From 1 Ton of Standing Timber (O.D. Basis)

1.	Stumpage - 1 ton (0.57 merchantable cords @ 5.00)	$ 2.85
2.	Procurement Fee - 1 ton @ 2.06	2.06
3.	Harvesting - 1 ton (0.57 merchantable cords @ 18.00)	10.26
4.	Chunk - 1 ton @ 10.00	10.00
5.	Haul - 1 ton @ 9.00 (40 miles)	9.00
6.	Yard - 1 ton @ 4.45	4.45
7.	Chunk Splitting - 1 ton @ 5.00	5.00
8.	Thaw - .949 tons @ 3.85	3.65
9.	Flake - .949 tons @ 8.44	8.01
10.	Dry - .949 tons @ 17.76	16.85
11.	Classify - .949 tons @ 1.06	1.01
	Total	$ 73.14

Cost per ton of +1/4 inch classification flakes

$= \frac{\$73.14}{.647 \text{ tons}} = \$113.04$

Cost per ton of +1/8 inch classification flakes

$= \frac{\$73.14}{.767 \text{ tons}} = \$\ 95.35$

The following calculations indicate the potential savings a 150 million square foot (1/2-inch basis) flakeboard plant could achieve by using the chunkwood system if it could utilize +1/8-inch flakes and had to pay $15.00 per cord for stumpage:

$$\$30.34 \times 150{,}000{,}000 \text{ ft}^2 \times \frac{.5 \text{ in-ft}}{12 \text{ in}} \times$$

$$\frac{42 \text{ lbs}}{\text{ft}^3} \times \frac{1 \text{ ton}}{2000 \text{ lbs}} = \$3{,}982{,}125 \text{ savings per year.}$$

Where specific cost elements are available, substitutions can be made to refine this estimate.

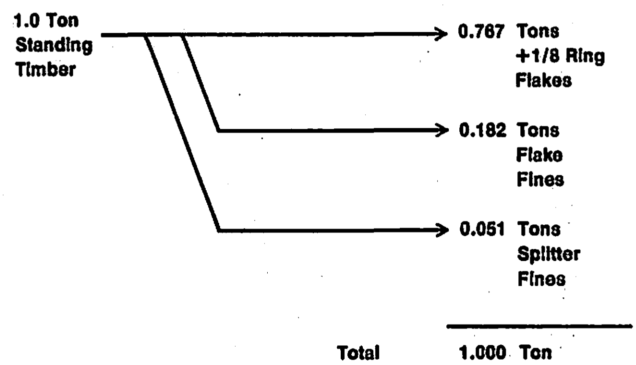

Figure 9. Material Balance for Producing Ring Flakes From Chunks From One Ton of Standing Timber O.D. (Oven-Dry) Basis.

CONCLUSION

Chunked wood, as produced by the U.S. Forest Service wood chunking machine, can be successfully used in the production of flakeboard. Mixtures of aspen flakes and soft maple flakes made from chunked wood can be utilized to produce random, oriented strandboard and highly aligned panels with strength and physical properties that meet or exceed commercial standards.

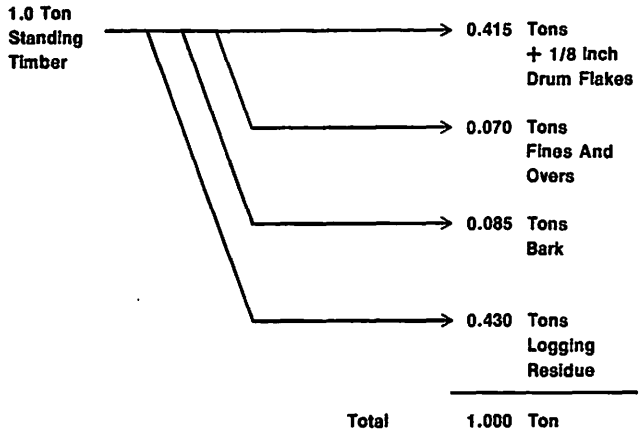

Figure 10. Material Balance for Producing Drum Flakes From Roundwood From One Ton of Standing Timber O.D. (Oven-Dry) Basis.

REFERENCES

1. Arola, Rodger A., Sharon A. Winsauer, Robert C. Radcliffe and Martyn R. Smith. 1983. "Chunkwood Production: A New Concept". Forest Products Journal. Vol. 33 No. 7/8 pp. 43-51.
2. Bryan, Richard W. 1981. "Composite Pine Panel Plant is the Last Work in Versatility". Forest Industries. Vol. 108 No. 4 pp. 34-37.
3. Dixon, Robert. 1981. "Elmendorf's 3-Ply OSB Receives APA Rating". Plywood and Panel. Vol. 24 No. 6 pp. 8-10.
4. Erickson, John R. 1976. "Exploratory Trials with a Spiral-Head Chipper to Make Hardwood 'Fingerling' chips for Ring Flakers". Forest Products Journal. Vol. 26 No. 6 pp. 50-53.
5. Gardner, Rulon B., Erwin L. Schaffer and John R. Erickson. 1978. "Converting Forest Residue to Structural Flakeboard - The Fingerling Concept". USDA Forest Service, Research Paper INT-200. 31 p.
6. Heebink, B.G. 1972. "Some Views on Large Structural Particleboard Panels". USDA Forest Service, Research Note FPL-0220. 8 p.
7. Heebink, Bruce G. and Raymond F. Dominick. 1971. "Forest Residues: Future Source of Particleboard". Wood and Wood Products. Vol. 76 No. 11 pp. 26-28.
8. Heebink, Bruce G., Erwin L. Schaffer, Joseph Chern and James H. Haskell. 1977. "Structural Flakeboards Using Ring Flakes From Fingerling Chips". USDA Forest Service, Research Paper FPL 296. 11 p.
9. Hse, Chung-Yuu, Peter Koch, Charles W. McMillin and Eddie W. Price. 1975. "Laboratory-Scale Development of a Structural Exterior Flakeboard from Hardwoods Growing on Southern Pine Sites". Forest Products Journal. Vol. 25 No. 4 pp. 42-50.
10. Northcross, Steve. 1982. "Potlatch Commits Minnesota to OSB". Plywood and Panel World. Vol. 23 No. 10 pp. 7-9.
11. Pease, David A. 1983. "Waferboard Production Unimpeded by Rejects". Forest Industries. Vol. 110 No. 4 pp. 32-34.
12. Price, Eddie W. 1977. "Basic Properties of Full-size Structural Flakeboards Fabricated with Flakes Produced on a Shaping Lathe". Proceedings of Eleventh Washington State University Symposium on Particleboard. pp. 313-332.
13. U.S. Department of Commerce. 1966. Mat Formed Wood Particleboard. Commercial Standard CS 236-66. U.S. Department of Commerce.

TRENDS AND PROSPECTS IN TIMBER HARVESTING, TRANSPORT AND CONVERSION[1]

Jochen Wippermann[2]

Abstract.--For harvesting and primary conversion a wide variety of forest machines is in use, also with special applications to different forest conditions, mobile as well as stationary equipment, e.g. power saws, processors as single function- and multi-purpose-logging-machines, chippers, skidders and forwarders, winches and grapples, truck mounted loaders, cable cranes, skyline systems, long transport vehicles for short logs, tree-lengths and full-trees. Since about 20 years there have been introduced well mechanized centralized conversion methods by forest owners or wood-using industries. Finally sawmills have got a sophisticated technology for processing of timber.

MECHANIZATION OF HARVESTING AND PRIMARY CONVERSION

The concept for system design of mechanized harvesting operations should include technical devices to ensure a larger yield of forest biomass or at least to reduce harvesting losses. For the time being the technological development can offer some interesting progress as compared with the degree of mechanization 10 years ago.

- Working systems at the felling site: full-tree, tree-length and short-wood systems

Logging methods: mostly thinning, partly clear-cutting, felling and topping at 5 or 7 cm by chainsaw, delimbing tree-lengths by chainsaws usually, harvesting machines for felling and/or delimbing are still rarely used. The most important stands in this region are at present in age classes of 25 to 40 years; processors for delimbing and cross-cutting have come more into use in the last 10, especially in the last 5 years, the number of them exceeds not more than 30 in the Federal Republic of Germany.

- Skidding methods: mostly by wheeled tractors equipped with double-drum winches, sometimes with grapple, and at some places with crane, with normal or articulated steering; generally tree-length system or full-tree system is applied in two-man operations in felling and skidding, or tree-length skidding by tractors with radio-controlled drums in one-man operations (France and Federal Republic of Germany). In Austria the combined operation of cable cranes, grapple skidding and delimbing/cross-cutting by processors at the roadside are favoured in mountainous harvesting operations.

- Intermediate storage of full-trees or tree-length is usually done along roadside.

- Operation at the roadside

The investments needed for a mobile debarking machine handling an average of 40,000 m^3 of spruce, pine and other conifers per year amount to about 800.000.- DM to 1 million DM; in the Federal Republic of Germany such machines (62), with a total capacity of 2.5 million m^3 roundwood, which debark tree-lengths at the roadside at many conversion sites all over the country, are needed by sawmills without debarking facilities of their own. But the bark stays unused in the forest, or left in small piles at the roadside.

- Operations at a central conversion site

The idea of rationalizing timber conversion by installing central conversion sites (CCS) is fostered by technological improvements of the last two decades and by the demand for intensive wood utilization. Highly developed forest industries need a well-managed flow of assorted timber from stump to mill.

The mechanization and centralization of primary conversion should be seen as part of a comprehensive system which includes stages of harvesting trees or logs and the subsequent stages of transport, storage and processing (secondary conversion) of timber.

The technological concept for centralized conversion with highly mechanized equipment finally evolved owing to the introduction of improved mechanical and hydraulic devices for the internal timber flow at landings, as well as of electronic devices for scaling timber volume, process regulation and operational control.

Such installations with high capital investments are becoming increasingly interesting from the energy point of view and help to make the high investments more advantageous although more

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electrical power is used. The advantages are as follows:

- conversion of tree-length logs or even of full trees
- higher value due to optimized grading of the log assortment
- direct marketing of any specially requested assortment
- use of residues, partly as wood chips and partly as fuel chips
- concentration of residues favours installation of CCS, but is more attractive to wood-using plants than to forest owners without utilization facilities of their own.

GENERAL EXEMPLIFICATIONS OF THE DEVELOPMENT TO CCS

The technical terms 'Central Conversion Site' (CCS) or 'centralized conversion landings', 'centralized processing yards', 'timber terminals' or 'lower landings' stand - according to a wood-utilization concept - for the concentrated conversion of timber, due to ECE/FAO/ILO-basic concepts and terms. This may be intermediate or permanent installations. Within a certain forest district, timber is harvested at various logging sites, accumulated in one place, converted at this 'central' point and afterwards distributed to linked plants or marketed over long distances. As many work elements as possible should be performed by machines - controlled by a few operators or skilled workers - at such a place, where the conversion of large masses of timber is concentrated from the point of view of transport lines or of the timber market. Thus the CCS can functionally be installed by the forest owner or forest products industry.

A vital factor in the successful use of the capacity and technology at a central conversion site - bearing in mind the very high investment costs - is the raw material itself. The following should therefore be defined in advance: whether the type of the surrounding forest is suitable for logging; whether the continuity of timber delivery from that catchment area is guaranteed; and last but not least whether the quality of the timber makes the production of a variety of assortments worthwhile.

At the end of such a process line convenient assortments of roundwood may accrue, e.g. saw and veneer logs, masts, poles, stakes, pitprops, pulpwood, wood for fibre, sometimes fuelwood, the number of assortments being determined by wood species, dimensions of trees, utilization features and, finally, the local or regional market.

Work has been facilitated by the reduction of time-consuming and physically hard manual work; therefore, the labour-force in forestry, sawmills and other timber industrues favours this mechanized working system whose design features ensure good ergonomic results.

In the Federal Republic of Germany the greater part of the mechanized conversion is carried out by stationary equipment than by mobile equipment, while in Austria the highest mechanization degree in harvesting operations is achieved at upper landings, mostly roadside places, when full-trees or tree lengths are brought by skyline systems in combination with grapple skidders.

RECOVERY AND HANDLING OF WASTES AT CCS

Centralized conversion not only meets the interests of production managements but also encourages wood industry plants more than the forest owners, who, in the Federal Republic of Germany, do not commonly run mills to utilize the residual material where it accrues in concentration. Branches, tops, bark, needles and occasionally leaves are turned into fuel for kiln drying facilities or power stations in timber industries. Up to 100% of the mass delivered to CCS or landings or mill yards may be used. Foresters and industry have gained sufficient experience to reach a surplus in recovery of about 6% timber volume by log length and full-tree logging.

In the last five years the interest in wastes has grown so much, at least for energy purposes, that the residues from conversion sites no longer have to be taken to a dump at considerable cost, but are collected by different conveyors and containers at the CCS. This method of waste recovery entails fairly high investments. The mechanical and hydraulic residual recovery system should be evaluated at not less than one tenth of the complete installation value. In the light of technical, ergonomic and economic criteria, it may be assumed that this investment outlay will be rapidly recovered.

For the construction of a new CCS with a yearly capacity of 20,000 - 30,000 m^3 spruce, delivered in tree-length with diameters between 16 and 24 cm and up to 22 m long, an investment of at least DM 150,000 should be calculated for all the conveyors and collecting system required to handle an average of 3,000 t wet weight of bark. The whole investment for the new CCS exceeds DM 1.5 - 2 million; in other words, the mechanical residue recovery system should be evaluated at not less than one tenth of the complete installation value.

YIELD BY VOLUME AND QUALITY

There are several advantages in transferring work elements of timber harvesting from the felling site to the CCS.

- better working conditions and technical facilities allow accurate scaling and cross-cutting, thus avoiding losses in volume and

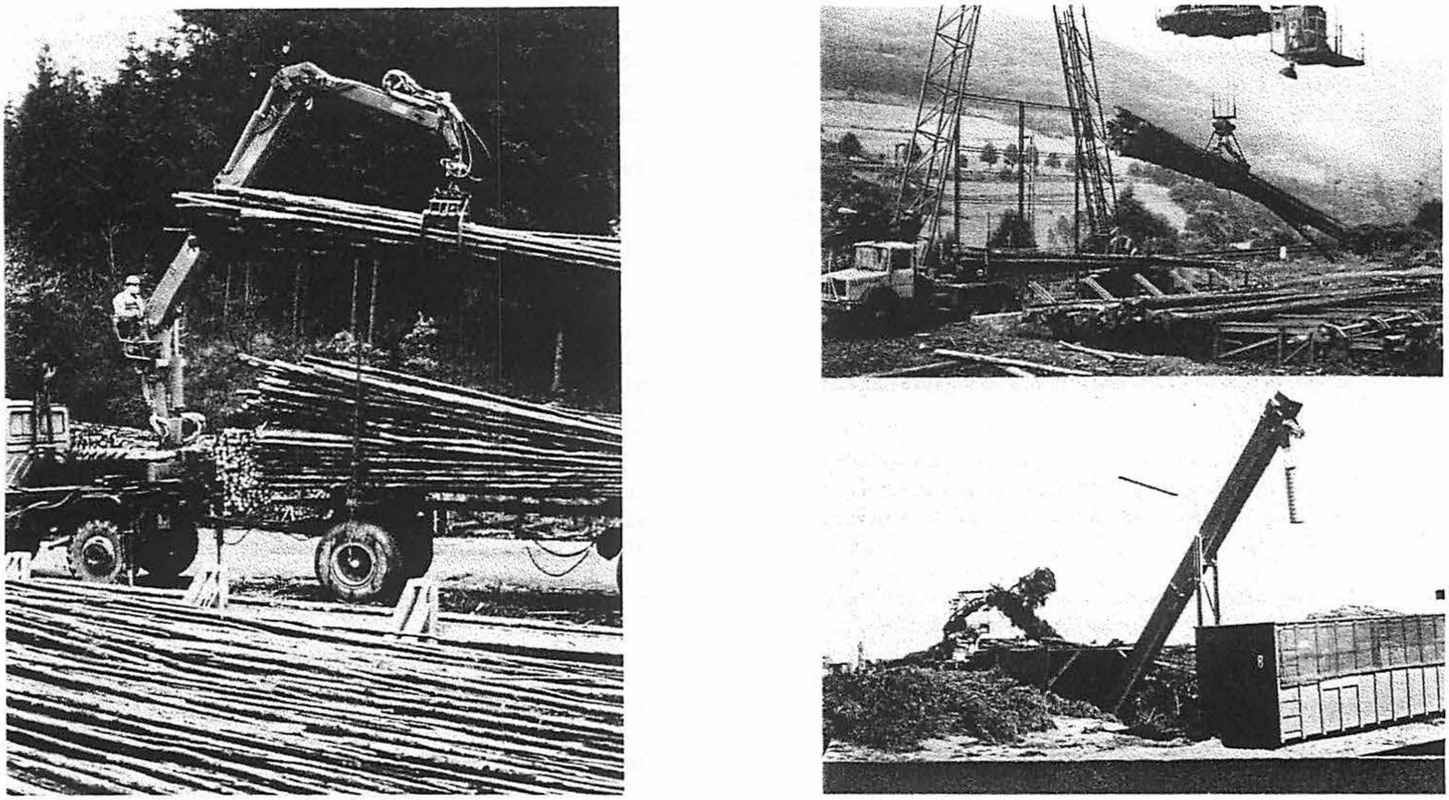


Figure 1. Infeeding operations at central conversion sites for tree-lengths and full-trees from thinnings.

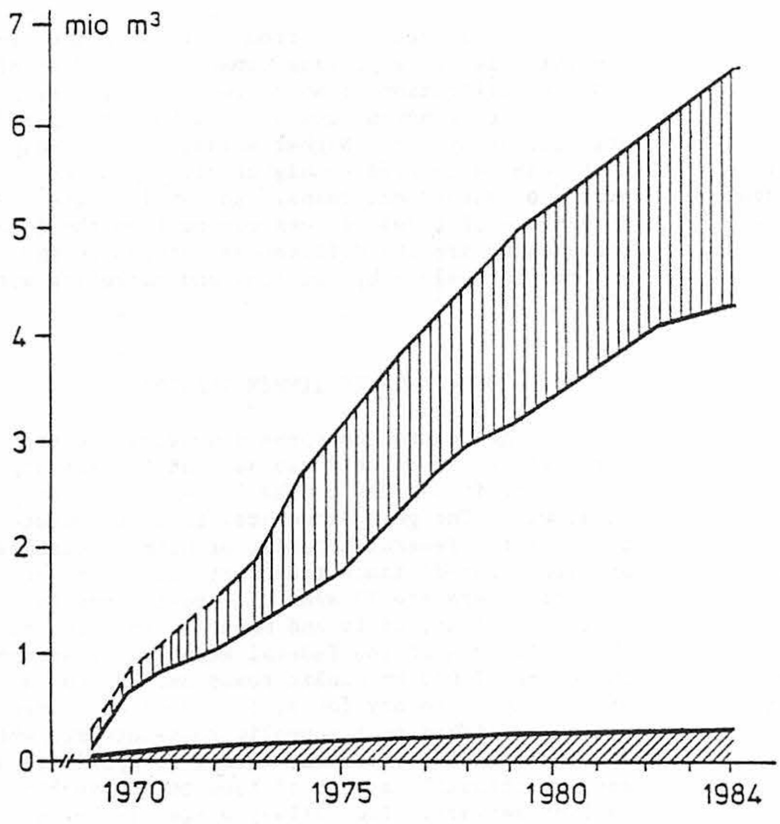


Figure 2. Mechanized debarking at central coversion site and at roadside in the Federal Republic of Germany.

grading;

- the forest owner will have more volume after selling the graded logs rather than the log stems;

- residual pieces at butt or top end remain unused when cut off in the forest, but are of some use as an offcut length on the longitudinal conveyor at CCS, where it will find a use anyway; only 2 to 3% of log lengths as cut-offs go to waste;

- even partly diseased logs can be marketed as lowgrade fibre, fuelwood and industrial or fuel chips;

- all small pieces of conversion residues can be gathered as industrial raw material or as fuel (branches, woodchips, bark, sawdust and needles);

- in past years bark and slabs had to be dumped, causing costs of between 3 and 6 DM/m^3;

- the residues get homogenized by introducing hammer-mills or drum-chippers;

- the bark can be sold to gardeners or to chemical industries;

- finally there is a yield by computing the grading in dynamic programming.

APPLICATION IN FOREST INDUSTRIES

The establishment of central conversion sites meets the goals of forestry and of the managements of wood-using industries for rationalization production processes. For many years now, a remarkable increase in the number of mechanized CCS can be observed in conjunction with sawmills. There are today about 250 yards and landings functioning as CCS in the Federal Republic of Germany. Most central conversion sites (about 90%) work in connection with wood-using industries; less than 5% have been set up by forest owners, and another 5% by timber dealers, preferably for small dimensioned timber.

Methods of centralized conversion have not yet changed, but the technology has been steadily improving. The capacity of CCS in the Federal Republic of Germany has grown, so that it is nowadays possible at some places to convert 100,000 to 200,000 m^3 (3 shifts) roundwood/year. At first CCS processed only spruce/fir but others were opened later for pine, especially in the northern part of the country.

Also in Austria several sawmills have been installed in the last few years, processing short saw-logs from spruce stands in the mountains with a yearly capacity of up to 100,000 m^3, in one place up to 300,000 m^3 roundwood. In France the biggest sawmill is processing up to 150,000 m^3, with primary conversion of tree-lengths in front of the mill. In the Netherlands there are some modern but smaller sawmills than in Austria or Germany which get tree-lengths and short logs; there the handling and sorting at a CCS linked to a mill are similar to the conditions in the Federal Republic of Germany.

ECONOMICAL CONSIDERATIONS OF HIGH CAPACITY CCS

Continuous delivery of log assortments facilitates rationalization of timber processing, while at the same time improving wood utilization in mill operations. The mills want roundwood assortments for all housing and construction purposes. There are only a few standard lumber measurements in the Federal Republic of Germany, France and the Netherlands, while Austria has standard dimensions for export markets. Expensive installations at the timber yards are needed in order to meet the requirements of conventional sorting and to reach high productivity at the conversion site.

However, with the increasing capacity of combined conversion and processing systems, e.g. a small-dimensioned timber line with trees on the CCS and lumber by the chipper-canter installation, new economic problems are cropping up at the timber market in highly industrialized countries, with a great density of sawmills.

To summarize, apart from increasing the yield possibilities by employing demand-oriented grading and the utilization of so-called wastes, there appear further advantages of this harvesting and utilization system. Higher skidding and transport costs can be covered by higher yield and net profit of assortment gains. The smaller the dimensions of trees or logs coming from the forest, the greater are the differences between buying and selling values by handling and marketing with CCS.

LONG-DISTANCE TIMBER TRANSPORT

In the Central European countries the transport network is quite dense so that forests and wood-using industries can be linked in a nearly ideal way. The good structural traffic connections of the Federal Republic of Germany enables excellent far-distance transport conditions of timber: there are 30 m/ha of forest roads in average of flat, hilly and mountain terrain, on the whole area of the Federal Republic of Germany there are 17.000 km public roads and 29.000 km of railways. So any forest is opened up by truck-roads and linked to the public road-network, while all industries have direct access to public roads and traditionally a part of them to the public railway network. The railway system is being reduced from 29.000 km (in 1980) to 18.000 or even 16.000 km in the long-range planning.

The yearly transport volume of timber ranges from 12 to 15 mio t in the Federal Republic of

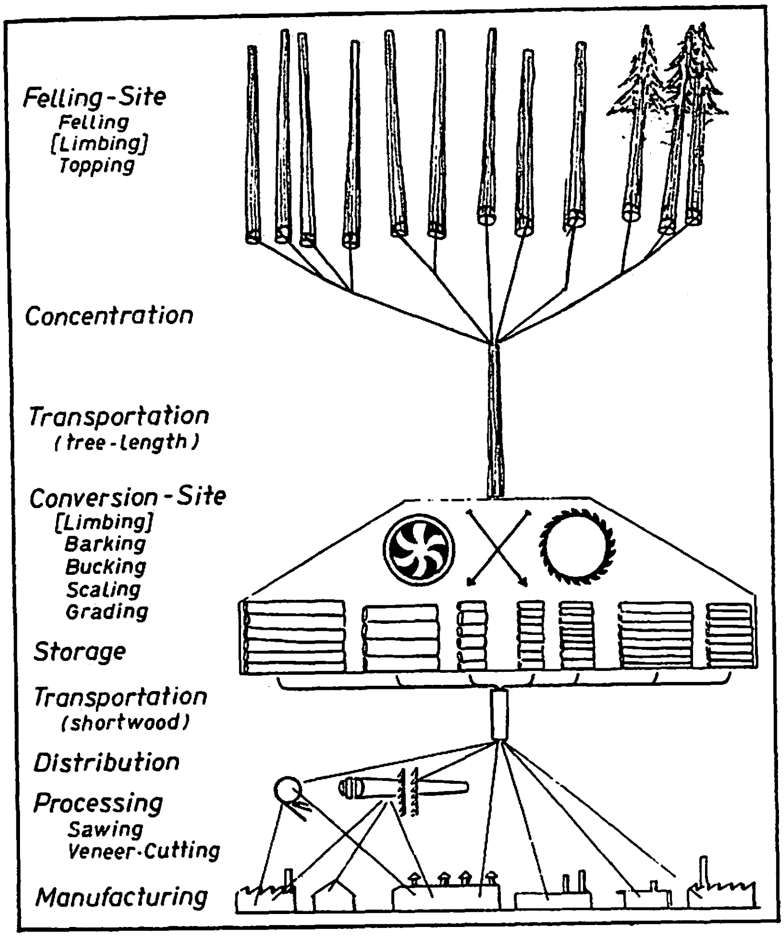


Figure 3. System of centralized and mechanized conversion.

Table 1. Harvesting costs for small-dimensioned timber from thinning stands, selected operations in spruce and beech in the Federal Republic of Germany.

Arbeitsverfahren	Holzart Sortiment	HEK-freier[x)] Erlös bei BHD cm m.R.	Holzerntekosten bei BHD 14 cm m.R.
EST-Standardverfahren	Fichte 2 m lg.	14-15	100,00
ROTTNE-SNOKEN-Processor	Fichte Abschnitte	14-15	95,23
Seillinien-Verfahren mit Kranprocessor auf Waldstraße	Fichte lang und Abschnitte	14-15	91,10
KOCKUMS-GP 822-Processor	Fichte 3 m	13-14	81,50
Schwedisches Bank-Verfahren mit Langkran-Tragschlepper	Fichte 3 m	12-13	79,84
Schwedisches Bank-Verfahren, manuelles Vorrücken	Fichte 2 m	13-14	79,64
Modifiziertes Goldberger-Verfahren	Buche lang	13-14	64,75
Winden-Durchforstungsverfahren	Buche lang	12	62,94

x) HEK = Holzerntekosten; HEK-freier Erlös (Variante mit 80% Lohnnebenkosten -LNK)

Germany, the smallest part of it (5%) is carried by inland navigation, 25% by the railway-system and 70% by road transport.

The timber transport by train is declining more and more, because of closing down unefficient and uneconomical branch lines of the railway system; on the other hand any interruption in the material flow rises the costs of transport. The timber has to be loaded on trucks anyway, because no direct access of train to forest exists. Today any transport distance up to 400 km is more economically to be overcome by truck than by train, though the investment for truck and semi-trailer has grown from 75.000.- DM to 300.000.- DM and fuel costs from 0.44 to 1.30 DM between 1968 and 1984.

The long-distance transport on the roads usually runs over 10 - 100 km, full trees over shorter distances (5 - 70 km) than tree lengths (up to 200 km in the Federal Republic of Germany mostly by short truck and semi-trailer, up to 27 m transport lengths for tree-lengths or up to 22 m truck-lengths for full trees).

The truck-transport of timber - full trees, treelength and shortwood - is possible and well managed in the following way today:

- 5-axles-truck and semi-trailer for highest possible transport capacity
- hydraulic loaders (cranes) for shorter cirlces of loading and unloading
- higher motor-capacity for shorter driving time
- technical devices to reduce time of maintenance, unproductive time, breaks, etc.
- loading at the roadside by mounted cranes
- one-man-operation (driving and loading)

There are many small companies of which the owner is mostly driving the truck himself. The payment system is based on t x km, the payment is done in DM/m^3 net weight.

RECOVERY SYSTEMS FOR RESIDUES AND UNCOMMERCIAL WOOD

The arrears in thinning stands, residues at most felling sites, growing demand for raw materials by the wood-using industries as well as the increase in wood prices and in energy costs are challenging for new operational way of recovery. Predominantly the biomass above the ground should be utilized to a greater degree.

Very high costs of harvesting timber in dense young stands, particularly felling and extracting trees from thinnings as labour-intensive operational elements in conventional residual recovery systems call for more productive working methods and better economic results. The conversion of residues after the normal logging process is the most expensive part of the whole harvesting operation in terms of m^3 of chips at the forest road side.

A process for recovering residues will be adopted by forest owners and workers as well as contractors and industrial managers if it works well; the feasibility of such an operation presupposes good design and productivity, ergonomic aspects, safe work and - last but not least - reasonable production costs. Fuelwood should be harvested and delivered with as much efficiency as industrial wood. But the propagation has to take into account the development of the timber market and fuel prices. For the time being in rural areas the interest in energy supply by the forest has grown up rapidly, while chipboard as well as pulp and paper industries are still sufficiently supplied with thinning material and industrial wood residues.

OPERATIONAL DESIGN FOR RATIONALIZATION OF CHIPPING

For the utilization of small trees or tree segments from thinnings and residual material from older stands different working methods have been applied. The unsatisfactory productivity and the moderate prices obtained for these scarcely-used raw materials demand for the use of machines which do not entail high investment and not acceptable operational costs. Intensive studies have therefore been carried out under different forest conditions in small-scale operations with special emphasis on private forest ownership, which accounts for 44% of forests in the Federal Republic of Germany now. More than one-half of the small estates scattered all over the country deliver fuelwood for residential wood-energy purpose. The fuelwood consumption for home-heating has been steadily increasing over the last years.

If the forest workers split or chip the fuelwood from thinning or other forest operations, residual recovery needs efficient motor-manual techniques and good organization of work, primarily for the working methods in the poorly mechanized private forest estates. On the other hand it should not be neglected that there rises the creation of employment opportunities through woodfuel harvesting. The conceptual ideas for these comprehensive studies since summer 1980 originated from the consideration to mobilize machines and men of farms or contractors for removing forest residuals by chipping in the forest.

TECHNICAL EQUIPMENT FOR A COMBINED CHIPPING AND FORWARDING SYSTEM

For the operational design it was hoped to develop a mechanized system of high mobility for carrying the chipper to the stump and forwarding

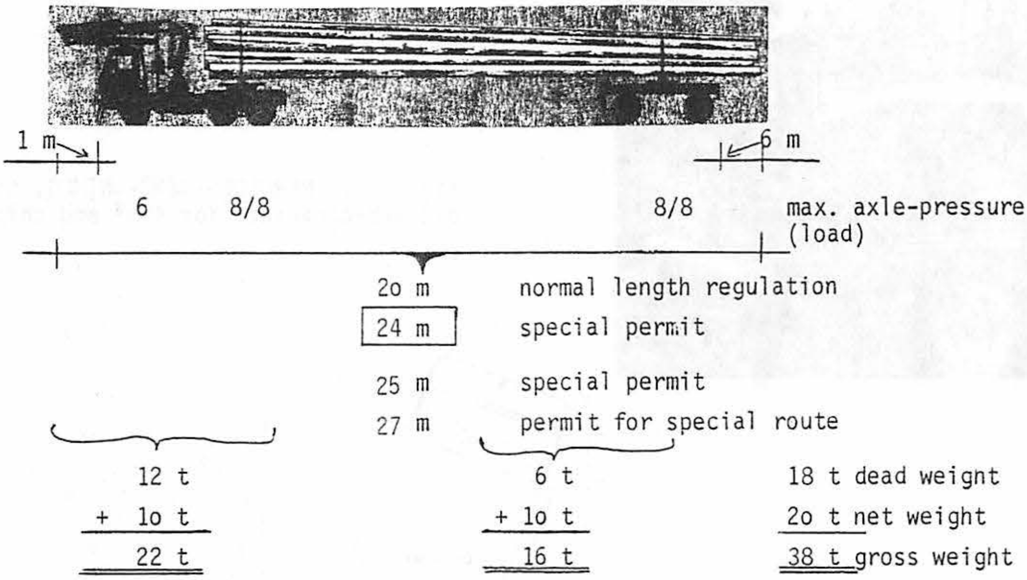


Figure 4 : Loading capacities and transport regulations for timber transport

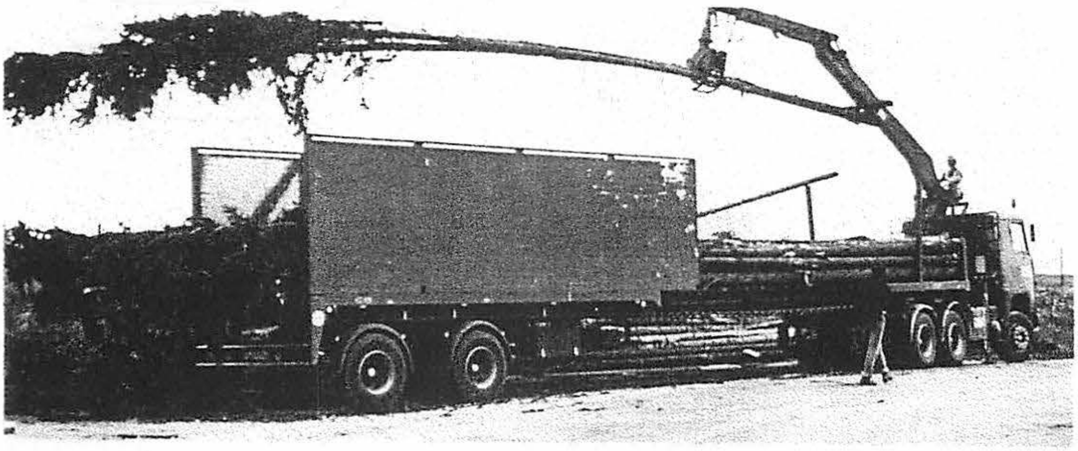


Figure 5 : Long-distance transport of full trees on public roads

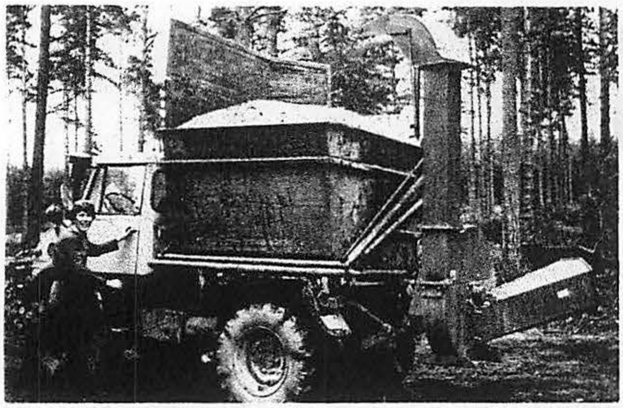
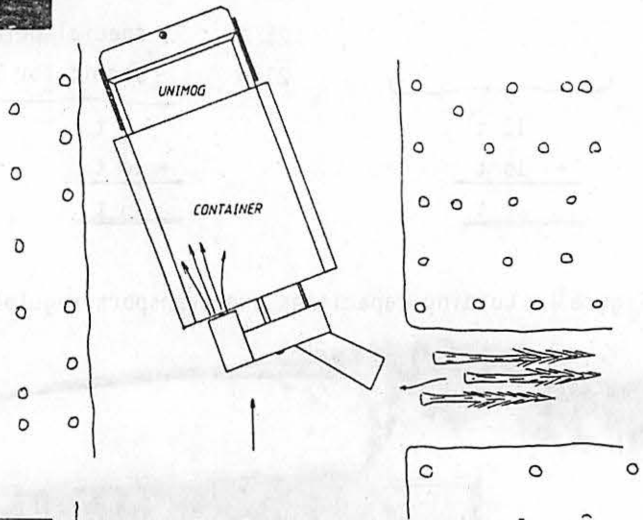


Figure 6. MERCEDES-BENZ-UNIMOG, tipping pick-up-container for 4 m³ and chipper.



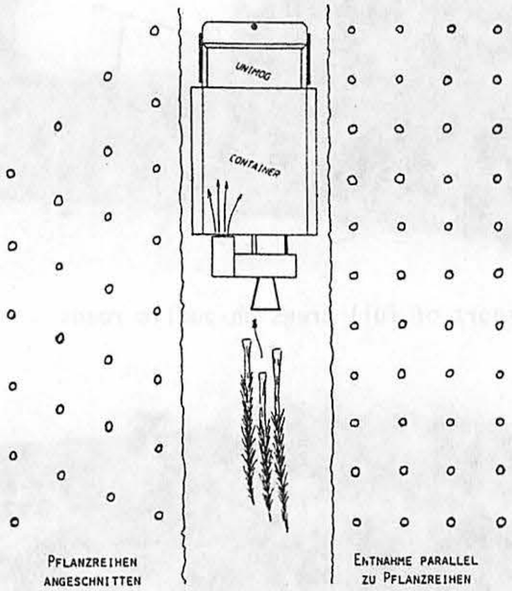
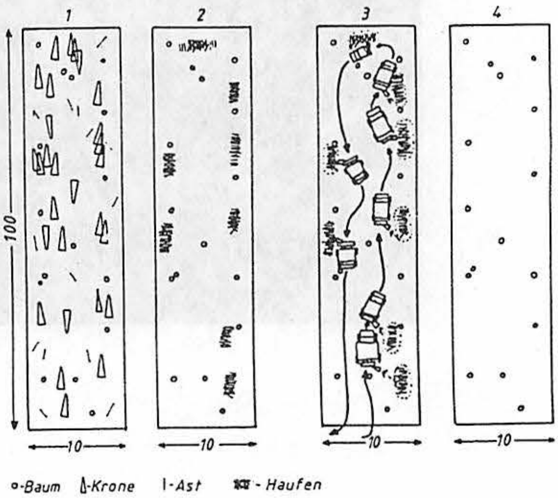


Figure 7: Machine combination in the skidding trail of pine stands

(above) operation for selective thinning

(left) chipping after strip-wise felling

(below) chipping residues under old-growth



the chips. The single machine should be a regionally widespread skidder or tractor, owned by farmers or even better by an association, equipped with a pick-up container and a chipper linked with power transmission in the rear. The machine which served for most of our studies is to be seen in the pictures beside.

Of the skidders available for driving the chippers and forwarding the chips in one single operation, only machines with more than 50 kW were regarded and proved as sufficiently powerful. Especially those skidders which could carry a container (2 to 4 m^3) besides the chipper were preferred (MB-TRAC, BM-UNIMOG, DEUTZ, WELTE, FENDT, etc.). It is very convenient to have a container catching the chips and to drive only with a two-axle vehicle on the skid trails as well as within the stands. Because of small operational areas in the size-class typical of private forest ownership, small-dimensioned, manually-fed disc-, helical- or drum-chippers should be used, with power transmission from the tractor.

PERFORMANCE OF THE MAN-MACHINE SYSTEM

The technical productivity of the studied and designed systems is measured under different working conditions and expressed in m^3 chips as quantity of reference to productivity or production costs.

In spite of most sales-promotion activities the hourly capacity of those small manually fed chipping machines does not reach 10 to 25 m^3 of chips/h but roughly 3 to 7 m^3/h, including feeding with prepared material, chipping and forwarding to the truck road. The lowest capacity is reached by removing residues under old growth, the best rate in the spruce stand where whole trees or segments of them have been utilized in a pre-commercial thinning operation. All experiences refer to two-men crews as well as in the preconcentration as in the chipping operation.

COSTS OF CHIPPING OPERATIONS IN THE FOREST

The most expensive work is the removal of residues under old growth stand at a cost of 41. - DM/m^3; the best results are achieved in spruce stands of about 20 to 30 year old beech (26. - DM/m^3), all data referring to the social cost situation and lower machine operating costs in private forestry. These costs appear very low compared to studies in other operations, which range from 30.- to 50.0 DM per m^3 chips delivered to the truck road; reasons for this are special design of the working system and its application in private forest ownerships.

The wages for forest workers and machine operators range from 12.- to 16.- DM/h, they differ among forest owners in the Federal Republic of Germany, especially there are beg differences in social costs, ranging from 70% in private enterprises to 130% in state forest enterprises on the wages. The private forest owner uses his farm tractor for harvesting work, while the state forest has a great number of special machines and this entails higher operational costs. Roughly speaking, in the state or municipal forest 40% can be added to the costs per m^3 chips mentioned above.

Generally fuelwood is coming from thinnings and clearcutting residues, which are removed by the consumers themselves from the stump in the most cases, paying about 30.- DM per m^3 at the felling site or 60.- DM per m^3 when it is already split and stacked at the forest road. Normally residuals are left back because of no economical value up to now. So long they are not processed to split pieces or chips they are not used as industrial raw material or fuelwood. On the other hand the returns from selling industrial roundwood for pulp and paper or chipboard industries cover scarcely the costs of harvesting and skidding in thinning operations.

STORAGE AND DRYING OF CHIPS

Biomass destined for fuel chips should be as dry as possible before delivering to storage or burner; in the optimal way it should be dried in the forest even with leaves before being chipped (leaf seasoning promises good results between May and September); when the biomass has been seasoned for some months at the felling site it should be chipped and go to storage. Wooden constructions for chip storage under roof but with open sides of a wire entanglement are recommended.

YIELD OF BIOMASS UTILIZATION

Especially in unthinned stands between 20 and 30 years a relatively high yield of biomass has to be taken off consisting of residues and small-dimensioned timber of no commercial interest. Many forest ownerships hold a considerable percentage of unthinned stands of which the biomass potential must be taken into account when normal silviculture methods and well-managed stands are aimed for.

Different silvicultural methods and harvesting intensities yield large amounts of biomass in each case; the following quantities which have been removed and chipped in the stands are to be seen in Table 2.

PROCESSING LINES FOR SMALL-SIZED TIMBER

The foreseeable development in the forest products industries allows a steadily growing utilization of small-sized conifers for sawn goods to be expected. The method of processing and the capacity of the processing line are influenced by factors such as supply of raw material, integrated production in combination with centralized primary conversion, accurate pre-sorting of well-graded timber, technology of processing, capacity, yield requirements, programme of sawn goods, investment needs and stresses at the working places. In addition to usual frame and circular saws, profile chipper-canters and bandsaws are in use now, as well as combinations, to set up efficient production systems.

Beech - 58 years, naturally regenerated, selective felling	74-11o m^3 HS/ha
Beech - 26 years, naturally regenerated, selective felling	6o m^3 HS/ha
Poplar - 17 years, planted, clear-felling (2 sites)	37o and 72o m^3 HS/ha
Pine - 76 years, naturally regenerated, selective felling	74 m^3 HS/ha
Pine - 25 years, planted, strip-wise and selective felling	6o m^3 HS/ha
Pine - 17 years, planted, strip-wise	14o m^3 HS/ha
Pine - 25 years, planted, clear-felling (after forest fire)	45o m^3 HS/ha
Spruce - 27 years, naturally regenerated, strip-wise and selective felling	18o-2oo m^3 HS/ha
Spruce - 3o years, planted, strip-wise felling	7o m^3 HS/ha

Table 2: Yield of biomass from different stands - species, operational methods, age-class, yield - (Aspen/Poplar, beech, spruce and pine)

Figure 8: Centralized conversion site (CCS) for conifers

SIMULATION OF MECHANIZED FELLING IN DENSE SOFTWOOD PLANTATIONS[1]

Sharon A. Winsauer[2]

Abstract.--Computer simulation of a feller-buncher operation was used to develop a regression model relating machine attributes to productivity while thinning dense softwood plantations. Factors most affecting productivity were machine travel speed, shear speed, accumulator head size, back up distance, bunch distance, and accumulator head size times shear speed.

INTRODUCTION

Throughout North America and Europe hundreds of thousands of hectares of closely spaced (1.5 to 2.75 m) softwood plantations need cleaning or thinning. Traditionally, the high cost and scarcity of skilled labor, combined with the fact that such thinnings produce little or no merchantable timber, have often made such thinning uneconomical. Recently, however, the development of machines such as chippers and chunkers have made it possible to reduce small trees to marketable products. These machines, along with the rising demand for wood energy and fiber, offer hope that the thinnings needed for stand improvement can break even or even make a profit.

To match the technological gains in processing machines, efficient techniques and machines for harvesting these small, closely spaced trees must be developed. Because of the close spacings and the possibility of bole and root damage, these harvesting machines must be small, lightweight, and maneuverable in addition to being efficient (Berg et al. 1975, Evert 1971, Low and VanToi 1974. Oswald 1974).

To develop new machines or harvesting concepts for these dense softwood plantations, the relation between machine design and productivity needs to be determined. As a step in this direction, we used a computer model to simulate a feller-buncher thinning a softwood plantation and to develop a regression model for productivity (fig. 1) (Winsauer and Bradley 1982).

The feller-buncher modeled has a chassis-mounted shear so it must be driven to each tree,

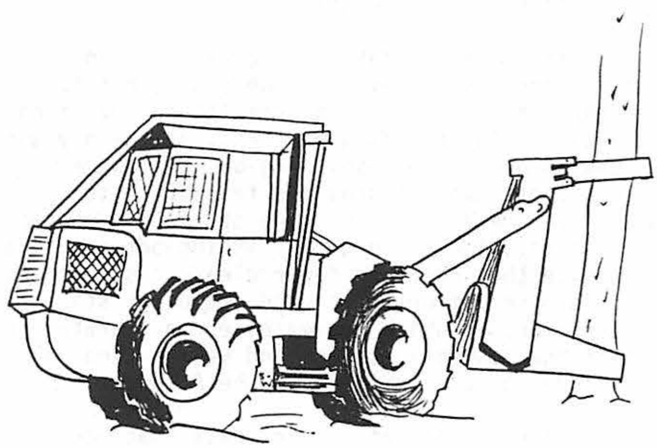


Figure 1.--Typical feller-buncher with chassis-mounted shear.

and the shear head must be accurately positioned. The assumptions used in the simulation are typical for small machines of this type. Thus, results are realistic, and data trends and comparisons should be valid; however, the specific numbers such as "172 trees/hour" may not match the production rate of any specific machine. Moreover, the theoretical study was limited to ideal, closely spaced softwood plantations so the results cannot be extrapolated to other stands or machines.

PROCEDURES

Feller-buncher productivity (trees/hour and/or tonnes/hour) is influenced by the following machine factors:

- Use of an accumulating head shear
- Shearing speed
- Machine travel speed

[1]Paper presented at the conference COFE/IUFRO - 1984. Orono, Maine, USA, 12-14 August.

[2]Sharon A. Winsauer is a mathametician at the Forestry Sciences Laboratory, North Central Forest Experiment Station, USDA Forest Service, Houghton, Michigan, USA.

If the trees are to be removed from the stand, the number of trees the feller-buncher collects into a bunch affects machine and system productivity. Small bunch sizes may result in high feller-buncher productivity but low skidder or forwarder production, so the system must be balanced accordingly.

This simulation study was limited to plantations of small-diameter, uniformly spaced softwoods. Spacings were from 1.0 to 2.5 m. All stands were assumed to have an initial basal area of 35 m^2/ha, giving an average tree diameter of 6.7- to 16.7-cm dbh. Work with slash pine (Collicot and Strickland 1968) showed the best growth to be in stands thinned to a residual basal area (BA) of 100 sq ft/acre (23 m^2/ha), so a thinning intensity of 33 percent (one-third of the initial trees) was simulated.

It is almost mandatory to clear a strip or machine corridor to get into the stand, but it is felt that thinning by strips results in poor form and growth. Two thinning patterns, strip-only and strip-with-herringbone-thinning-between, were tried. These two patterns are feasible alternatives for mechanized thinning of closely spaced plantations. The strip-with-thinning-between is a compromise that requires fewer clearcut strips and leaves a more uniformly thinned stand but still has corridors in which the machine can operate. A list of the assumptions made and values used in the simulation can be found in the Appendix.

Earlier investigations indicate that accumulating shears, faster shear rates, and faster travel speeds increase feller-buncher productivity (Newham 1970, Winsauer *et al*. 1984). To develop equations relating machine productivity (trees/hour) to these and other significant factors, simulation runs were made using various machine rates and stand spacings. Trees/hour, tonnes/hour, trees per bunch, and percent of total time spent shearing, traveling, etc. were recorded for each run. Then regression models were proposed and equations developed. Finally, test runs were made to verify the equations and refinements made as necessary.

The simulation model was written in the simulation language GPSS (General Purpose Simulation System) (Schriber 1974). The simulated thinnings were carried out on the Sperry 1100/80 at Michigan Technological University, Houghton, Michigan.

PRODUCTIVITY REGRESSION MODEL

For a feller-buncher with a chassis-mounted shear, the following prediction equation for productivity while strip thinning was developed based on 55 simulation runs:

$$
\begin{aligned}
\text{Productivity (trees/hr)} = {} & 22.9 \\
& + 8.45 \text{ ave. travel speed (k/hr)} \\
& + 3.17 \text{ ave. shear speed (trees/min)} \\
& + 37.9 \text{ accumulator size (trees/load)} \\
& - 3.27 \text{ accumulator size}^2 \\
& - 4.74 \text{ backup distance (m)} \\
& + 2.52 \text{ acc size x shear speed} \\
& - 1.31 \text{ bunch distance (m)}
\end{aligned}
$$

Multiple correlation coefficient - R^2 = .95

Standard error of estimate (S.E.E.) = 18.16

Sample Calculation - For Strip-Only Thinning

Productivity (trees/hr)		
	= 22.9	22.9
	+ 8.45 x 5 k/hr	42.2
	+ 3.17 x 5 trees/min	15.8
	+ 37.9 x 4 trees/load	151.6
	- 3.27 x 16 (trees/load)^2	- 52.3
	- 4.74 x 10 m	- 47.0
	+ 2.51 x 4 x 5	50.2
	- 1.31 x 10 m	- 13.1
		= 170.3 trees/hr

As you can see, the feller-buncher productivity rate was about 170 trees/hr for average conditions. The production rate ranged from less than 50 trees/hr (no accumulator head, slow travel speed, and long backup distance) to more than 400 trees/hr (accumulator holding eight trees, fastest shear, and no backup distance).

Productivity in terms of tonnes/hr can be determined from the trees per hour and the size of the trees; for example, 170 trees/hr would be 4.3 tonnes/hr for 6.7 cm trees, or about 15 tonnes/hr for 16.7 cm trees.

DISCUSSION

Several interesting facts came to light while testing and refining the prediction model.

1. Although tree spacing is a significant variable where wide spacing is used (Ashmore *et al*. 1983, Bradley 1984), adding a tree-spacing term did not improve the fit of the model to the data. Because of the close spacings in the stands considered (1.0 to 2.5 m), tree spacing had little effect on productivity.

2. Tree diameter did not directly affect trees/hr felled. The trees are small enough (maximum 16.7 cm) that positioning and shear time depend upon the hydraulic capacity rather than stem diameter. Tree diameter does have a major, indirect effect--for a given accumulator head size, the average number of trees/load depends upon average diameter at breast height (dbh). The same size accumulator may collect eight small (6.7 cm) trees for a load of 200 kg but average only 3.3 large (16.7 cm) trees per load (approximately 300 kg).

3. As the sample problem shows, the trees per accumulator load greatly influenced the production rate. It is not a linear effect, however--a change from no accumulator head (one tree/load) to two trees per load can increase production rate by 50 trees per hour while a change from 7 to 8 trees per accumulator load shows little improvement.

4. Another significant effect on production rate is the strong interaction between shear speed and accumulator capacity (fig. 2). Although productivity would be expected to improve with a higher shear speed or with the addition of accumulating ability, I did not expect such a great cumulative increase.

When an accumulator head is used, travel is reduced; therefore, a greater percentage of the time is spent actually shearing trees. And of course, the more time spent shearing, the greater the effect of changing shear speed.

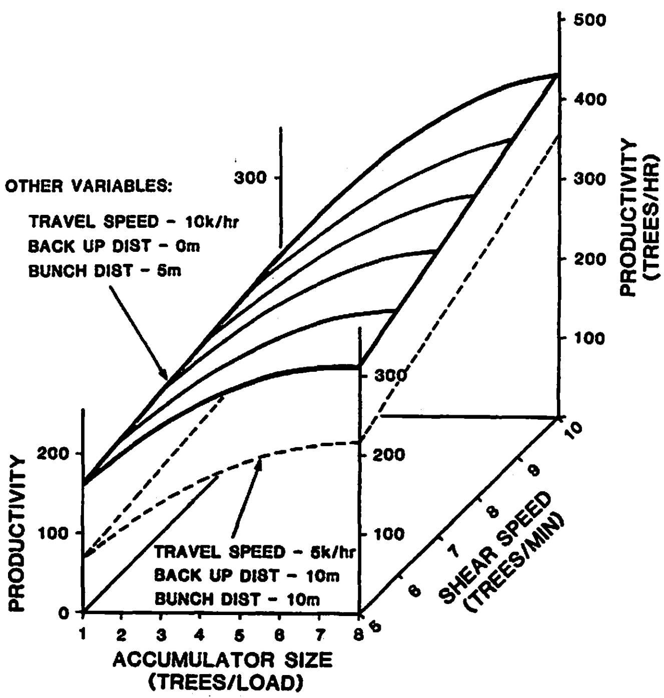


Figure 2.--Feller-buncher productivity--strip thinning in dense softwood plantations.

Accumulator size (trees/load)	Average travel per tree (m)	Travel time (percent total)	Shear time (percent total)
1 (no acc)	30.8	51.9	23.4
8	4.5	20.6	70.8

Although it may not be possible to develop a machine that can reach the theoretical 8 trees per load and still operate without damaging the closely spaced remaining trees, it is important to note that an increase in shear rate along with an increase in the number of trees per load would be much more effective than an increase in either factor by itself.

5. Another variable that was more important than anticipated was the "backup" distance. The original assumption in the model was that the machine working in the narrow strips would shear the tree(s), "back up" one tree length (10 m), drop the tree(s), then drive forward over the downed tree(s) to the next tree. If this backup distance could be reduced or eliminated by a new machine design, productivity would be increased. On the other hand, as the "backup" distance gets longer, it becomes more and more important to have an accumulator head.

6. A slightly higher correlation coefficient, R^2, could have been obtained by adding other terms involving combinations of backup distance, accumulator size, shear speed, and travel speed. However, these additional terms did not increase the R value sufficiently to warrant the increase in model complexity.

7. The last factor in the equation, "bunch distance," is the extra distance the feller-buncher operator will travel to create larger bunches for the skidder or forwarder. The extra "bunch distance" was selected as a variable to make it independent of stand spacings and other variables. In small-tree stands where it is costly to remove the wood, it would help to have the stems bunched and ready to skid. The feller-buncher can do this, but at what cost? To determine the effect the operator's decision has on productivity, runs were made simulating various "bunch distances." A regression equation was developed relating the number of trees/bunch the feller-buncher collected for the skidder to the choice of bunch distance. Two other major factors affected bunch size--stand spacing and accumulator head size.

$$\text{Trees/bunch} = 7.13 - 3.56 \text{ spacing (m)} + 0.527 \text{ accumulator size (trees/load)} + 0.613 \text{ bunching distance (m)}$$

$R = .91$ S.E.E. $= 1.46$

Test runs were made varying "bunch distance" from 0 to 20 m. Trees per bunch varied from one (no bunching) to 22; the largest bunch was in the 1-m stand thinned with a machine with a large accumulator head and an operator willing to back up an extra 20 m to increase the bunch. This increase in bunch size can decrease feller productivity by 25 trees/hr.

THINNING IN A STRIP-WITH-HERRINGBONE PATTERN

The strip-with-thinning-between pattern selected for simulation was to cut a strip every sixth row and to thin the intervening five rows in a herringbone pattern.

The distance traveled per tree is greater when using the herringbone pattern, making travel time greater and overall productivity less than for strip-only thinning. When no accumulator head is used, the distance per tree increased about 10 percent, while productivity (trees/hr) decreased 5 percent (table 1).

The greatest loss in productivity is caused by the lack of full utilization of the accumulator head. The machine must leave the strip, and it would not be feasible to try to maneuver into the between-strip areas with the accumulator head already partially loaded. Therefore the accumulator loads are only 60 to 70 percent as large as those in the strip-only thinning. This results in a net productivity loss of up to 50 trees/hr.

At the same time, the number of trees collected in a bunch for removal from the stand is much larger when thinning between. Because of more trees to be cut from any strip location when no accumulator head is used, the bunches are twice as large as in the strip-only situation, and are 50 percent larger when a large accumulating head is used. The possibility of more efficient skidding could offset the slightly higher felling costs, particularly in the case of a non-accumulating head feller-buncher.

The bunch size when thinning between strips depends upon stand spacing and backup distance but not upon accumulator size for the stands and machines simulated. Some care would have to be taken, particularly in the closest spacings, to prevent the bunches becoming so large as to obstruct the passage of the feller-buncher.

CONCLUSIONS

New and better ways to mechanically thin closely spaced softwoods need to be developed. In addition to the need for small, maneuverable machines, the most important machine concepts to explore and develop appear to be ways of cutting and/or collecting multiple stems at once. If this can be developed in conjunction with a faster cutting head, the production rates could be greatly increased.

Another area of possible improvement would be to find some way of stacking the stems or dropping them immediately at the stump and yet not hinder forward motion of the feller. If the backup and/or positioning travel the feller goes through to drop and/or bunch the felled trees can be eliminated, efficiency would noticeably improve. Still another possibility would be to have the felling machine do no bunching other than what is done while cutting, followed by a "clearing" machine that could sweep through the strip rows and remove the felled, unbunched wood from the stand.

APPENDIX

Tables 2 to 4 contain the assumptions and data used in the simulation model. For a more complete discussion of input values, see Winsauer et al. 1984.

Table 1.--Comparison of thinning in a strip-with-herringbone and strip-only pattern.

	Productivity		Bunch size		Average acc load		Total Travel distance	
	Herr	Strip	Herr	Strip	Herr	Strip	Herr	Strip
	(trees/hr)		(trees/bunch)		(No. of trees)		(m/tree)	
No acc head[1]								
1-m spacing	72	76	20	10	1.0	1.0	33	30
2.5-m spacing	69	73	9	4	1.0	1.0	36	32
Large acc head								
1-m spacing	172	221	23	15	5.0	8.0	9	5
2.5-m spacing	120	152	9	6	2.5	3.3	18	11

[1]Other parameters values - shear speed = 5 trees/min, travel speed = 5 k/hr, backup distance = 10 m, and bunch distance = 10 m.

Table 2.--Initial stand characteristics.

Assumptions	
Species	Softwood (generalized)
Stand structure	Plantation - square spacings
Terrain	Flat
Strip length	100 m
Basal area (before thinning)	35 m^2 ha (150 sq ft/acre)
Tree volume	
(m^3)[1]	0.021 + 0.00048 x dbh^2 cm)
(ft^3)	0.73 + 0.109 x dbh^2(in)
Tree height (m)	10
(ft)	33
Wood density (green basis)	
(kg/m^3)	600
(lb/ft^3)	37
Thinning intensity (% trees removed)	33

Variables	Range
Tree spacing[2]	
(m)	1.0 to 2.5
(ft)	3.3 to 8.2
Ave. tree dbh[3]	
(cm)	6.7 to 16.7
(in)	2.6 to 6.6
Stand density	
(trees/ha)	1,600 to 10,000
(trees/acre)	648 to 4,050

[1]Volume equations were developed from combined data of several softwood species (Winsauer and Steinhilb 1980).

[2]For each stand spacing, average tree dbh selected to give a B.A. of 35m^2ha.

[3]Individual trees dbh selected from a distribution with a range average stand dbh ± 2 cm.

Table 3.--Operational factors.

Assumptions

Chassis-mounted shear:

Feller must move to each tree to fell it.

To reach a tree outside the strip, it must back up an equal distance for maneuvering.

All felled trees will be laid in the strip. The feller will back up, drop the trees, and drive over them.

Maximum distance the feller will back up to add to a bunch is 20 m (65 feet).

Desired bunch size for economical skidding (sum of tree diameters)	(cm)	200
	(in)	80

Thinning patterns: Strips-only or strips with herringbone thinning between strips (fig. 3).

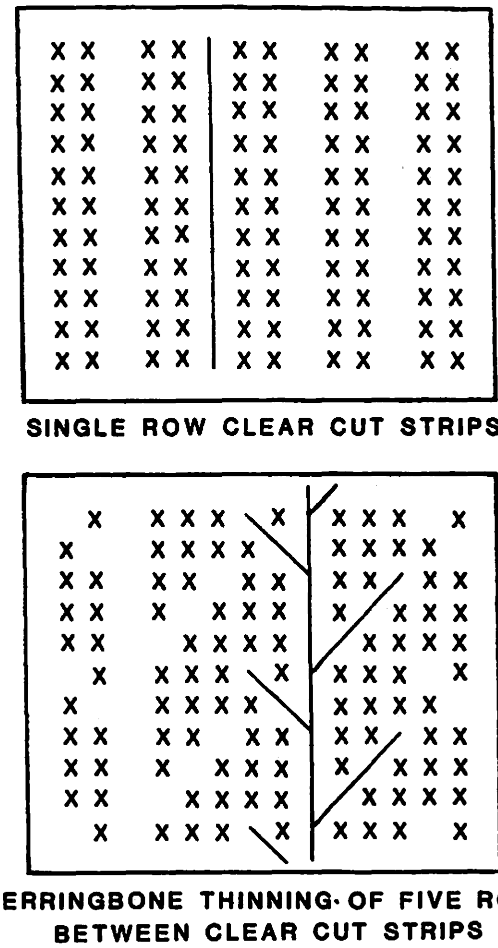


Figure 3.--Thinning patterns to achieve a 33 percent tree removal.

Table 4.--Machine characteristics.

Variables	Range
Shear accumulator	
Capacity - total sum of tree diameters (dbh)	
(cm)	No accumulator to 55[1]
(in)	No accumulator to 22
Average travel speeds[2]	
Chassis-mounted shear	
(k/hr)	2.5 to 10.0
(mph)	1.5 to 6.0
Average position and shear time[3]	
(min/stem)	.1 to .2
Average drop time	
(min/load)	.2

[1]Maximum size accumulator can hold up to 8 small but only 3 to 4 large trees.

[2]Individual travel speeds taken from normal distribution.

[3]Individual shear times selected from normalized empirical distribution multiplied by average.

LITERATURE CITED

Ashmore, Colin, Bryce Stokes, Bobby L. Lanford. 1983. Thinning performance of the Hydro-AX411 in fifth row removal. ASAE 1983 Winter Meeting, Chicago, IL. 18 p.

Berg, Hans, Per-Ove Backstrom, Runar, Gustavsson, and Bjorn Hagglund. 1975. Systems analyses of cleaning of young stands. Logging Research Foundation Report No. IE 1975, 80 p. Skogsarbeten Drottninggatan 97, S-113 60 Stockholm, Sweden.

Bradley, Dennis P. 1984. Using computer simulation to evaluate mechanized harvest systems. Technical Bulletin 1687. Washington DC: U.S. Department of Agriculture, Forest Service, Canada/United States Spruce Budworms Program. 39 p.

Collicott, L. V., and J. R. Strickland. 1968. Growth related to density following first thinning in slash pine plantations. Technical Note No. 26, 8 p. Forest Research Notes. Southlands Experiment Forest, Bainbridge, GA.

Evert, F. 1971. Spacing studies - a review. Forest Management Institute Report No. FMR-X-37, 95 p. Canadian Forest Service, Department of the Environment, Ottawa, Ontario, Canada.

Low, A. J., and G. A. VanToi. 1974. Initial spacing in relation to stand establishment. p. 296-300. IUFRO proceedings from symposium on stand establishment. [Wageningen, The Netherlands, October 15-19, 1974].

Newham, R. M. 1970. Productivity of harvesting machines designed for thinning: estimation by simulation. Forest Management Institute Report No. FMR-X-25, 29 p. Canadian Forest Service, Department of Fisheries, Ottawa, Ontario, Canada.

Oswald, H. 1974. [Station de silviculture et de production I.M.R.A./G.N.R.E, Nancy, France]. p. 320-342. IUFRO proceedings from symposium on stand establishment. [Wageningen, The Netherlands, October 15-19, 1974].

Schriber, Thomas J. 1974. Simulation using GPSS. John Wiley & Sons, New York, NY. 533 p.

Winsauer, Sharon A., and Dennis P. Bradley. 1982. A program and documentation for simulation of a rubber-tired feller/buncher. USDA Forest Service Research Paper NC-212, 34 p. North Central Forest Experiment Station, St. Paul, MN.

Winsauer, Sharon A., James A. Mattson, and Michael A. Thompson. 1984. Feller/bunchers in plantation thinnings: factors affecting productivity. USDA Forest Service Research Paper NC-254. (Manuscript in process.) North Central Forest Experiment Station, St. Paul, MN.

Winsauer, Sharon A., and Helmuth M. Steinhilb. 1980. Summary of green weights and volumes for five tree species in Michigan. USDA Forest Service Research Paper NC-191. North Central Forest Experiment Station, St. Paul, MN.

RECENT ADVANCES IN OFF-ROAD FOREST VECHICLE DEVELOPMENT IN SCANDINAVIA [1)]

Esko Mikkonen [2)]

Abstract. Due to historical background and forest ownership structure, the shortwood harvesting systems have been prevalent in Scandinavia. Research and development work in mechanization of harvesting has therefore been concentrated on the machines and methods applicable to the shortwood systems.

The future development in the short run seems to follow the same line, though there are new materials and technologies being introduced; e.g. aluminium frames, advanced hydraulics, electronics, automation and robotics.

New requirements are set, however, for decisions regarding productivity and costs of the machines for harvesting thinnings. These are environmental issues, working conditions and safety. They will affect the machine design in the future, as will the ever increasing internationalization of the forest machine manufacturing business.

INTRODUCTION

Shortwood systems have been traditionally used in the logging and transportation of timber in Scandinavia. This is due to the large number of forest owners and the small size of their woodlots where extensive large-scale operations cannot be performed. The number of wood sales have thus been large. The timber measurement procedure applied to shortwood systems is widely accepted. Labour intensive logging methods have been used because the unit costs of the manual methods were lower than those of the mechanized methods till the late 1970's.

Logging and transportation operations have been managed and performed either by the timber buyer or the seller in many farm forest operations.

Forestry was traditionally a part of the farm economy. Only in Sweden a larger share of forest land is owned by the forest industry companies. State forests are generally located in remote and environmentally sensitive areas where full-scale operations are not allowed. The forest ownership structure has changed. There are more urban forest owners who obtain their living from other professions than agriculture and forestry.

Another reason for the wide use of shortwood systems has been limited capability of the mills to handle tree lengths or full trees. This has restricted the development of new logging methods and machinery.

Finland and Sweden are countries where shortwood systems have reached a pre-eminent position.

The research and development of equipment and machinery as well as methods has almost entirely supported shortwood applications.

One can find two clearly different lines of mechanization in logging and hauling of timber. The other is based on the use of typical farm tractors in forest operations and farmers' wood deliveries. In the other, almost everything, from whole tree logging for stationary wood handling terminals to small tractor operations, have been tried. Here, the shortwood logging with processors, harvesters and forwarders has established itself as the prevalent method. The share of the last mentioned line has increased during recent years.

Other features typical to Nordic logging are the large share of selective thinnings, vast areas of bogs, snow problems caused by the long and often severe winters, etc.

In the next chapters I will try to outline the present situation of hauling wood and its mechanization in Finland and Sweden. The logging is also dealt with as long as the off-road machinery is concerned.

Finally, the effects of new technology on Nordic off-road forest machine design will be discussed.

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1) Paper presented at the joint conference COFE/IUFRO -1984. Fredericton, New Brunswick, Canada, August 17.

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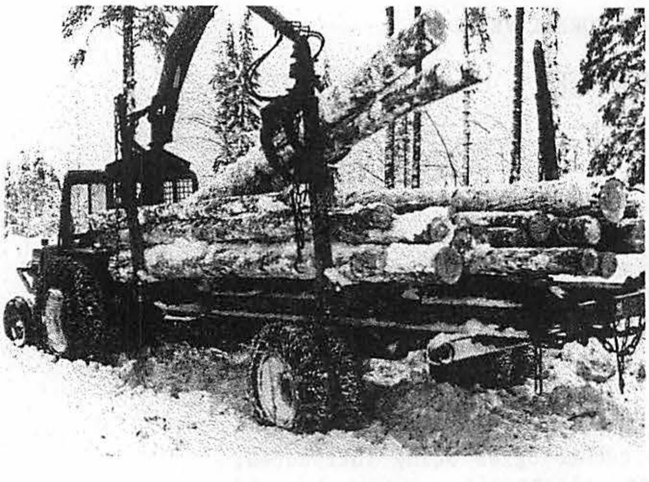


Figure 1. A Typical farm tractor of the early 1970's in forest operation

Figure 2. Modern Valmet 802 farm tractor equipped for forwarding wood

CURRENT METHODS AND MACHINERY

Farm tractors in forestry

As earlier mentioned there are two separate lines of mechanization. First, a few words about farm forest operations.

There are nearly a half million farm tractors in use in Scandinavia. A great number of them are also used in logging operations every year. The following methods are applied.

(1)	Felling, delimbing and bucking in the woods	+	Forwarding by farm tractor		
(2)	Felling and delimbing	+	Tree length skidding	+	Bucking at landing by power saw
(3)	Directional felling	+	Delimbing and bucking by farm tractor mounted processor	+	Forwarding by farm tractor

Method 1 is most common. A farm tractor can be equipped with a winch, skidding grapple, hydraulic loader, and a forest trailer which can have driven axles and boggies. During winter time a timber sledge can be used.

These methods are applied in about 20 - 25 per cent of the total volume harvested yearly in Finland. In Sweden the figure is somewhat smaller.

Farm tractors are bigger than earlier, they have four wheel drive, a turbocharged engine, power shift transmission and a safety cabin. Regardless of development, farm tractors are still primarily designed to be used on fields and not in the woods. Therefore, they can be used in good terrain only under favourable conditions if high productivity is maintained simultaneously. This is not the case, however, in many farm forest operations where a farmer tries to get extra work hours for his otherwise underemployed tractor.

Figure 3. Valmet forwarder of the early 1970's

Figure 4. Modern Bruunett mini 572 forwarder is equipped with double boggies

Farm tractors are not used in forestry for other tasks than hauling and transportation of wood. In the picture review one can see the recent development of the Nordic farm tractor for forestry (Fig. 1 and 2).

Off-road vechicles in harvesting

The most common off-road vechicle in Scandinavian forestry today is the forwarder. Other vechicles such as skidders, excavators, bulldozers, snowmobiles, etc., are rather rare. The design of the forwarder is based on a wheeled construction. Other design principles such as tracks or air cushions are not generally used.

As such, forwarders are used for hauling logs and short pulpwood. They are basic machines for several applications like feller-skidders, processors and harvesters. Forwarders are used to pull forestry equipment; e.g. planting machines are built on forwarders, etc.

For hauling timber, three size classes of forwarders can be found. Classifield by the gross vechicle weight, heavy forwarders weigh 25 - 33 tonnes, medium sized 15 - 25 tonnes and light weight forwarders 10 - 15 tonnes, when fully loaded.

Forwarders are used in the following logging methods:

(4) Manual shortwood cutting + Forwarder

(5) Manual felling + Processor at strip road + Forwarder

(6) Feller-buncher + - " - + - " -

(7) Harvester + Forwarder

(8) Feller-clambunkskidder (Forwarder frame) + Delimber at landing

(9) Manual felling + Forwarder equipped with a grapple saw

Feller-bunchers are the only specially built machines in which forwarder chassis are not used as the machine base.

Methods number 4, 5 and 9 are also used in thinnings if the forwarder size is approriate.

Medium sized and heavy forwarders can be equipped with a long-reach hydraulic loader.

Typical features for a modern forwarder are articulated steering, hydraulic-mechanical transmission, boggies both in front and rear, hydraulic loader with long reach, and ergonomically designed safety cabin in which all the operator functions are easy to perform.

The modern forwarder is a highly specialized machine which has undergone tremedous development to become the versatile machine it is today. The picture review features some of the development trends during the past years (Fig. 3 and 4).

CHALLENGES OF THE FUTURE

The social environment for forestry is changing rapidly. The number of urban forest owners is still increasing and for them, other aspects, other than wood production, are more important in forest owning. If wood is to be harvested it has to be done more carefully than to-date. This creates an urgent need for development of lighter and environmentally acceptable harvesting technology. The volume from thinnings will increase greatly if all the activities needed for the right forestry measures and achievement of production goals are to be met. For this reason there is a special need to develop selective thinning technology.

The costs of human labour have increased fast due to high social security costs. It has been profitable to mechanize logging. Another reason has been the effort to make the logging work more productive and easier, and also to raise the safety of the forest work.

Energy crises have created requirements that the wood raw material has to be utilized better than earlier. New technology applicable for it, is to be developed. The optimization of raw material utilization requires full trees or at least tree lengths, to be transported to the mill.

The huge increase in productivity of forest machines has decreased the home market for the machines during recent years. This in turn means that the forest machine manufacturing business must internationalize its activites in order to maintain the same volume of sales. The problem is how to fit the production for the international market. The next question is whether the shortwood systems widely used in Scandinavia, but not elsewhere, are the right ones.

According to the facts above the following requirements for the forest machines of the future can be set:

(1) Machines must be lighter and their transport payload has to be increased

(2) Thinning machines have to be smaller and lighter

(3) Damages to the growing stock caused by the machines have to be minimized

(4) Forest work must be safer than earlier, i.e. less accidents and not cause permanent injuries or diseases i.e. back injuries, white finger disease, etc., to the workers

(5) Increase in real machine costs has to be stopped i.e. the productivity must be raised

(6) Methods and machines to be developed must not prevent better utilization of the raw material

HOW TO MEET THE CHALLENGES

Forest machines can be constructed lighter and their transport capability increased in two ways:

- to design them better
- to use lighter materials

For the first task the use of the CAD/CAM will provide good help for the designer.

New construction materials such as vacuum steel, aluminium (Fig. 5), modern plastics, carbon fibers and ceramics will decrease the weight of the machines considerably. It is estimated that the forest machines could weight 30 - 40 % less than today. Some experiences of the new materials are already now available. The decrease in weight will increase the load by the same amount (fig. 6).

For thinnings a wholly new machine size must come into use. Its dimensions must fit the thinning instructions of various stands. The ideal new machine could be designed for all types of harvestings, including clear cuttings.

If the machine is equipped with tracks (Fig. 7) or wide profile tires the ground damages will be negligible.

The movements of a long reach loader can be controlled by a microprocessor with programmes applied in robotics. A microprocessor controlled transmission will allow even traction and thus minimize tearing of the ground surface.

Figure 5. Aluminiun frame of the Ponsse forwarder has reduced the gross weight considerably

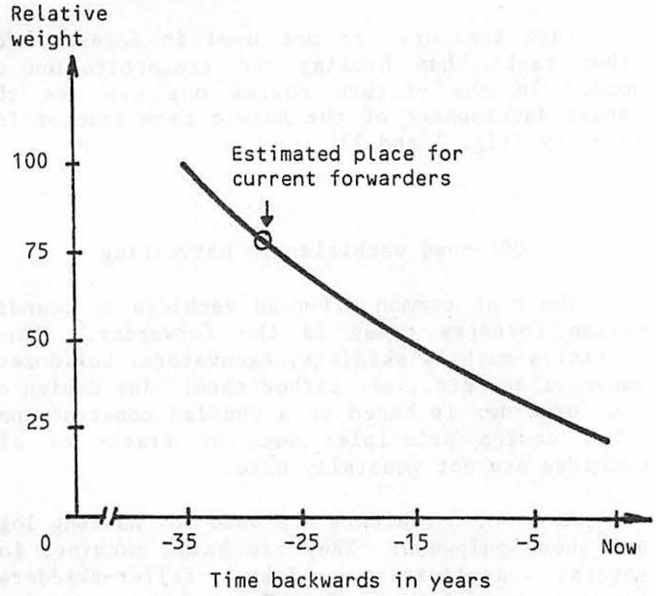


Figure 6. Relative weight reduction curve of the professional chain saw and the weight reduction possibilities for forwarders

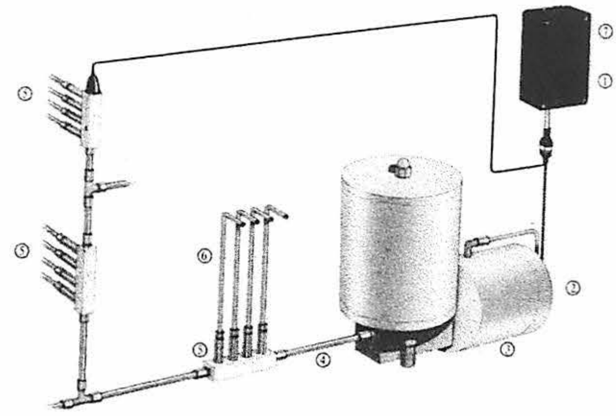
Redesign of the cab and its better suspension will decrease whole body vibrations. Better ergonomic design of the operator seat, panels and lever positions will prevent fatique.

The increase in machine costs and thereby the unit costs of harvesting can be slowed down by utilizing automation. Applications in forest machines are for instance

- automatic lubrication systems (Fig. 8)
- microprocessor controlled loader movements
- remote control and automatic driving systems

The machine prices can be kept down by manufacturing longer series. This requires internationalization, however, because the home markets

Figure 7. Farmi-Track is a modern tracted forwarder for thinnings



1 Control unit
2 Magnetic valve
3 Hydraulic pump
4 Body pipe
5 Dosing modules
6 Lubrication pipe
7 Signal light

Figure 8. An automatic SAFEMATIC™ lubrication system for vechicles

are shrinking due to faster productivity increases, than the growth of the business. The international marketing must be taken into account in designing special methods and machines, as forest machines are.

A good example of a new application of the proven method and machines is the part tree method with forwarders equipped with a grapple saw. This combination utilizes the raw material much better than earlier methods.

CONCLUDING REMARKS

There will be no drastic change in the Scandinavian harvesting technology in the short run. Shortwood systems will stay dominant. They will be developed toward utilizing more part tree methods. Special machines and applications of the current machines (Fig. 9) for this will be developed according to the facts stated above.

Figure 9. Forwarders of the future will be lighter and smaller. Norcar is one example of them

In the longer run the use the tree length or full tree systems, at least in some part of the harvesting, will be reconsidered. Better utilization of the trees will require all the parts of the trees to be transported to the mills.

LITTERATURE CITED

Andersson, Stig. 1982. Ny teknik i skogen. (Swedish only). Secretariatet för framtidsstudier. FRN. Trosa. Sweden

Kaarnametsä, M. 1983. Kevyen teknologian toteuttamismahdollisuudet. Metsäkoneseminaari 15.12.1983. (Finnish only). (Seminar on forest machinery). Koneurakoitsijain liitto ry. Helsinki. Finland

NSR. 1984. Nordic Research Council on Forest Operations. Conference Report 13. - 16.2.1984 from Rovaniemi. Ås. Norway

The Rationalization Conference, 1983 - 1984. 1984. Report no. 1. The Forest Operations Institute of Sweden. Stockholm. Sweden

FOREST OPERATIONS IN NORTHERN CHINA

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SUMMARY

Beginning in the 1950's, Northeast China's logging operations achieved significant successes in the development of improved systems and technology for logging. The logging operations changed from manual/animal to mechanized, from short-wood to tree-length, from seasonal to year-round. After decades of exploitation the surviving forests are limited mainly to the more inaccessible steep regions. Tractor skidding has been preferred in the Northeast, but cable yarding is getting wide use. As terrain transport distance is getting longer (1-1.5 km), more than one type of extraction has to be used for log transport from the stump area to the roadside landing. Existing combinations of off-road transport are described. The trees to be harvested are getting smaller and the plantations are maturing, equipment for thinning is under development.

China contains about 120 million ha (296.4 million acres) of commercial forest, 16 million ha (39.5) of thinly stocked forest and 4.5 million ha (11.1 million acres) of plantation. The forest cover is only about 12.7% of the total land area. Most forests grow on inaccessible mountainous areas, unsuitable for agriculture. In 1949, the timber production amounted to 5 million cubic meters. However, as economic construction developed, the need for timber increased rapidly. During the last ten years, the annual timber production in China has been estimated at 40 million cubic meters. This figure represents only that part of timber distributed by the special state-owned company. The actual annual cut is much more, perhaps three or five times.

Being one element of an integrated forest management plan, forest harvesting in China is mainly undertaken by state-owned enterprises, called forestry bureaus, with annual harvest quotas of 100,000-500,000 cubic meters, while the collective farmers in South China also cut timber on a smaller scale. The timber production has been concentrated in Northeast China, including Heilongjiang and Jilin Provinces as well as the Inner Mongolian Autonomous Region, where most of China's forests, about 60% of total forest resources, grow. Timber production in the Northeast accounts for about 40-50% of the total. Mature and overmature mixed coniferous-broadleaved stands constitute the main part of the forest resources to be harvested with red pine, birch and larch being the dominant species. Most terrain of this region is gentle with an inclination of less than 25 degrees. The stand yield is about 100-200 cubic meters per ha with the average tree-length volume 0.3-0.7 cubic meters. The frost-free period amounts to 120-140 days per year. Due to continuous intensive harvesting, the annual cut has exceeded growth, and timber harvesting has been transferred from gentle to more steep terrain.

Before 1954, logging operations in Northeast China were carried out manually, felling with one-man curve-handle crosscut saws and axes, delimbing with axes, crosscutting with saws and skidding with horses and oxen. All logging operations were conducted only in the cold season, taking advantage of the frozen ground covered with ice and snow to use sledges for timber extraction. The timber was loaded onto a rail car manually and then transported to concentration yards by narrow-gauged railway cars. From 1955 crawler skidders (KT-12 and later TDT-40) were introduced from the Soviet Union which made possible tree-length harvesting and year-round operations. Since then, manual shortwood harvesting and seasonal operations were almost replaced in the Northeast. Chainsaws were used for felling and bucking while axes were still used for debranching. Winches with stationary wooden booms were employed for cross-hauling loading. During the period from the end of the 1950's to the beginning of the 1960's, ice-snow chutes were widely developed due to lack of fuel for skidders. About 50% of the timber was extracted manually from the stump area by gravity along these chutes in 1960. Afterwards, the fuel supply improved and machinery operated again. In 1980, the proportion of mechanized extraction amounted to 97% in Heilongjiang Province. From 1982, however, animal skidding has risen again, constituting 11.2% in Heilongjiang, because in some difficult terrains the animal skidding cost is lower than tractor skidding. The proportion of seasonal logging has also increased rapidly. Timber, produced in the cold season, amounts to more than 80% of the total of the annual cut in some enterprises. The productivity of skidders in winter is 50% higher than that in summer when the bearing capacity of forest ground is low, and muddy skidding roads have to be filled with branches or even timber crossties to strengthen them. Timber consumption on skidding roads is figured at 0.3 cubic meters per cubic meter of log produced. Although in some forestry bureaus logging operations are carried out seasonally, long distance transport continues year round. The tree-lengths skidded to the roadside landings must be piled, which results in value loss due to deterioration of wood quality and tieing up of funds. Logs are usually not debarked and transported in tree-length form to depots.

All logging machines used in the Northeast are made in China. The first chainsaw was introduced in 1959, model 051, and now four models (051, GJ85, CY5, YJ4) are manufactured in China. In spite of the high level of noise (110 decibel) and vibration (20-25g), the 051 chainsaw is popular with the loggers of Northeast China. It is distinguished by its' high offset handle bar which enables the operator to fell trees without bending down, reducing fatigue significantly. The wire rope recoil starter can be removed and stored in a pocket after use. The chainsaw is powered by a 2-cycle 3-hp gasoline engine and is hand oiled. It weighs 11.5kg (251 lbs). The sawbar head can be rotated 360 degrees each way, so it can be easily changed from felling (horizontal) position to bucking (vertical) position or vice versa without rotating the whole saw body. However, it cannot be used for limbing, which is still done by axes. Models CY5 and YJ4 are conventional chainsaws with short handles.

In Northeast China, tractor skidding is preferred. Two types of skidders are used. One is the Jicai 50 crawler, the other is the Jicai 80 wheeled skidder. The crawler skidder, most popular in this region, is powered by a 50-hp diesel engine through a five-speed transmission. Equipped with a single drum winch and frame bunk on the rear, which can be raised and lowered hydraulically to carry the front end of the tree-length off the ground, this machine has been widely used for more than 20 years. It was specially designed for skidding in forest terrain, and has a skidding capacity of 8-10 cubic meters in the winter. The Jicai 80, a 4-wheel drive skidder, was introduced in recent years by the same plant. Equipped with an 80-hp diesel engine and 10-speed transmission, as well as bunk and winch on the rear, this articulated skidder travels much faster than the crawler and is mainly used for long distance skidding or secondary offroad transport on modulate terrain (less than 20 degrees), while the crawler works on steeper terrain. Both crawler and wheeled skidders use chokers to attach tree-lengths to the winch cable. Logs are usually skidded downhill to the valley floor, where the forest roads are located. Cable yarding has also been increased in recent years, as the forest resources located on gentle terrain has been largely harvested and the cutting has moved to steep slopes (more than 25 degrees) where the remaining stands grow. All yarders used in China are semistationary, mounted on sledge legs and powered by engines ranging from 25 to 70 hp. Both skyline and highlead systems are used for extraction, with priority given to the first one.

Although over 10,000 km of narrow gauged railways and thousands of forest roads have been built during the last decades, the density of the forest road network is still limited due to the difficult terrain and lack of capital investment. This resuslts in extremely long offroad transport distances (1-1.5 km). To solve this problem, some forestry enterprises have employed measures such as relay or secondary off-road transport. Timber is transported from stump area to roadside landing by combinations of 2 or 3 types of terrain transport. The existing combinations of off-road transport can be described as follows:

(1) Skyline + wheeled skidder
(2) Crawler skidder + skyline + wheeled skidder
(3) Crawler skidder + wheeled skidder
(4) Highlead cable system + wheeled skidder
(5) Highlead cable system + crawler skidder + wheeled skidder
(6) Crawler skidder + cable-railway*
(7) Skyline + cable-railway

Although China has manufactured front end loaders, due to their lack of adaptability the main log loading equipment in the Northeast is still the simple stationary devices. A set of blocks is hung in two gin poles supported in an inclined position by

*The cable-railway operates like a pendulum. When the loaded car goes downhill, the empty car is pulled uphill.

guylines. Cable from the winch of a tractor or yarder is used for cross-haul loading, with the mainline attached to the winch cable. In some places simple cable cranes are also used for log loading. A winch-operated overhead cable is strung between two wooden spars across the road. A carriage rides on it and lifts logs to be loaded.

After loading, tree-lengths are hauled by narrow-gauged railway cars or trucks 30-100 km to log yards, where they are unloaded, bucked, sorted, stacked and distributed to users. Log yards are actually rail reloads. Facilities in log years are more permanent. The level of operation mechanization is higher than that of forest operations. Winch-operated spar-cable systems or gantry cranes are used for unloading. Portable electric chainsaws are widely used for bucking, while a set of fixed circular saws is also used. Most yards use conveyors for log sorting. Winch-operated A-frames and bridge cranes are used for stacking and loading onto railroad cars.

The forestry enterprises in the Northeast are all comprehensive, undertaking planting, tending, silviculture, harvesting and sawmilling. Most forestry bureaus have sawmills nearby log yards, consuming 10-50% of timber produced by the bureaus. There are also plywood and wood-based panel mills in some forestry bureaus.

Attention has been paid recently to utilization of logging residue, which were left in the site in the past. Utilization of branches, twigs and leaves has just begun. Some are used to support local fuel needs, while large branches are turned by mobile chippers into salvage materials suitable for pulp and fiberboard. Utilization of logging residue will be expanded in the near future, because the forest resources to be harvested are declining.

Most of the logging machines used in the Northeast were developed more than 20 years ago. Their technical-economic indexes are behind modern standards. These machines cannot meet the needs of ergonomics and operation safety. For instance, the 051 chainsaw, designed in 1959, has an excessive weight and relatively low cutting efficiency. The level of noise and vibration is much higher than that of overseas chainsaws. The Jicai 50 skidder, developed in 1964, has a poor cab, where the operator suffers severe cold and heat in the winter and summer respectively. In particular, there is no protective structure, such as ROPS (roll-over protective structure), FOPS (falling object protective structure) or OPS (operator protective structure). These machines need to be replaced. Forestry machinery plants have worked on developing new machines, which are going to replace the existing old ones. The new modified model GJ85 chainsaw's vibration has been decreased from 25g to 5.29g. A mobile yarder with tower is under development to meet the need in harvesting timber on steep slopes. Equipment for thinning has also been developed, such as the Yinglin 35 and Yinglin 55, both articulated wheeled skidders. The Yinglin 35 is equipped with a hydraulic grapple.

In 1976 and 1980 a small amount of modern logging machines was imported from Finland and the United States, including feller-bunchers, feller-skidders and processors, which have been tested in Northeast China. Results indicated that this expensive sophisticated machinery is not suitable for the present stage of development in China despite its high efficiency. China is a developing country with abundant labour resources and extremely low labour cost (about 40-50 times lower than that in industrialized countries). Considering the social and economical point of view, for the time being it is not desirable to develop such complicated machines. However, economic construction in China has been developing rapidly since 1980, the employment situation is improving and the wage rate is increasing, so the time for using these machines will come eventually.

The tree-length harvesting system, i.e. both skidding and hauling in tree-length form, will remain predominant. However, in some particular places, where the forest resources are scattered and terrain is difficult, short-wood animal skidding and skidding by ice-snow chutes may be used to a certain extent. Because the period, when economic profitability was neglected, has gone never to return. Both seasonal and year-round operations will remain.

Forest roads are essential not only to log hauling, but also to all forestry activities. Silviculture and management cannot be undertaken without roads. The density of the forest road network in Northeast China is expected to increase from 3.5 to 10 m/ha. The existing narrow-gauged railroad will be maintained while truck roads will be built.

The main problem in silviculture involves cutting and regeneration. Emphasis had been put on cutting in the 1950's and 1960's, while regeneration had been neglected. Afterwards selective cutting took the place of clearcutting on the majority of areas harvested while natural regeneration was relied upon in many areas. However, selective cutting is falling into disfavour because of misapplication and unsuitability. Often noncommercial species tend to take over in preference to the desired commercial species, and regeneration is difficult. Therefore, the preferred system is now clearcutting, followed by planting. Clearcutting is often done in strips ranging from 50-200 m with an area restriction of 5-10 ha. Even with planting, it is difficult to get the desired species to dominate the young stands. This is particularly true in the broadleaved-coniferous mixed forest because birch and other species quickly invade the cutover areas and compete with planted trees. So the predominant planted species is not the well-known red pine, but larch, which is easier to regenerate though not as commercially important as the red pine. Many forest scientists are working on regeneration of the valuable species - red pine.

THE FELLER FORWARDER CONCEPT AND ITS APPLICATION[1]

John Kurelek, P. Eng.[2]

Abstract. The feller-forwarder concept has been implemented into a well-developed full-tree logging system particularly suited to poor stands and rough terrain. It offers a very high man/day productivity and a tidy operation at a low level of mechanical complexity. Its application requires close attention to stand and terrain characteristics.

Intensive development of the feller-forwarder was begun in North America in 1976. By 1980, it was making inroads as a preferred full-tree system. This growth has now been almost stopped as machine costs have jumped, labour is generally easily available, and wood harvest volume needs reduced.

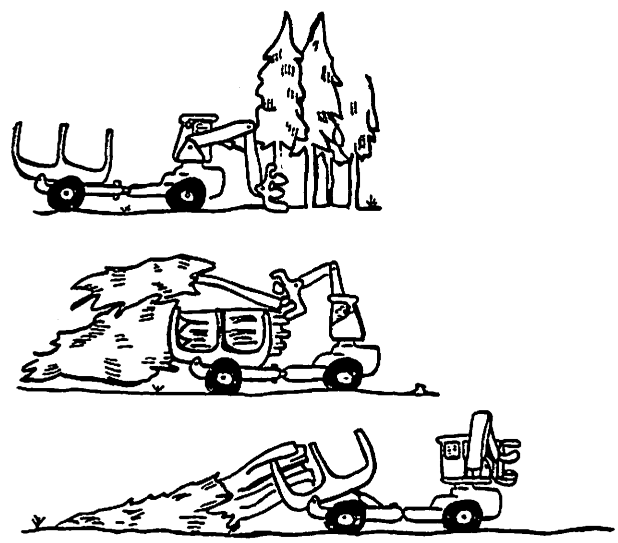
There are approximately 75 machines out in the field, some now six years old, and most users consider the concept to be their best system. They would seriously consider it for additional capacity or equipment replacement.

Its proferred advantages are listed as:

- a high man/day productivity
- low wood cost
- clean wood
- low biomass loss
- clean, low disturbance site effect
- good worker job quality
- simple mechanization

If we accept the SAE definition for our purposes here, then the operation is simply to drive to the tree, fell it onto the machine, and haul it to roadside.

The practical applications to date embody a fairly large four-wheel drive vehicle, a multiple tree-collecting felling boom, and a dumping container.



Although it is a simple procedure requiring the introduction of little complexity into the woods, it did require some components that were not available, namely, a multiple tree-gathering head, and an off-road vehicle capable of carrying full trees off the ground. Early experiments hence usually persisted in felling the tree into a holding rack for the butts only, allowing the tops to drag. Such ideas offered small machines and good manoeuvrability, but, unfortunately, never solved the problems of having to break static sliding friction with every tree-to-tree move and the load disturbance of repeated arm opening and closing. The needed componentry came during the early 70's in answer to the impetus for stump area harvesters and feller-bunchers. Trees could be accumulated in a swinging boom-type felling head, and large wheels were operating to the stump.

The intrinsic advantage of a feller-forwarder, at first, seems to be that it saves material handling; but, besides that, it probably does well at both the felling and the wood transport functions as well.

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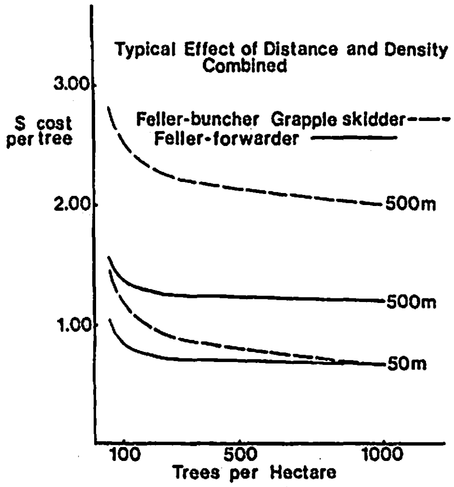
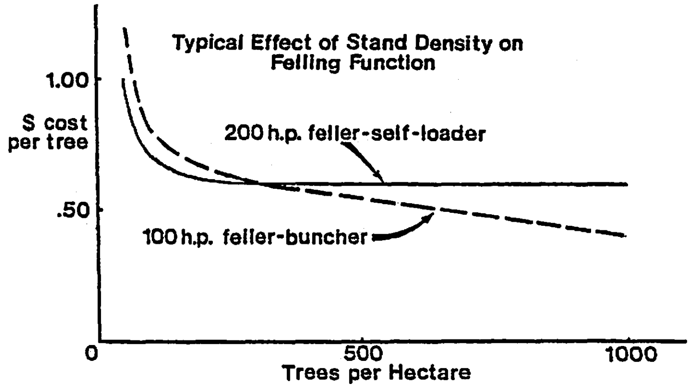
[1]Paper presented at the COFE/IUFRO Symposium - 1984. Fredericton, New Brunswick, Canada, 15-18 August.

[2]John Kurelek is a mechanical engineer doing forest-related equipment analysis and design in independent practice in Brantford, Ontario, Canada.





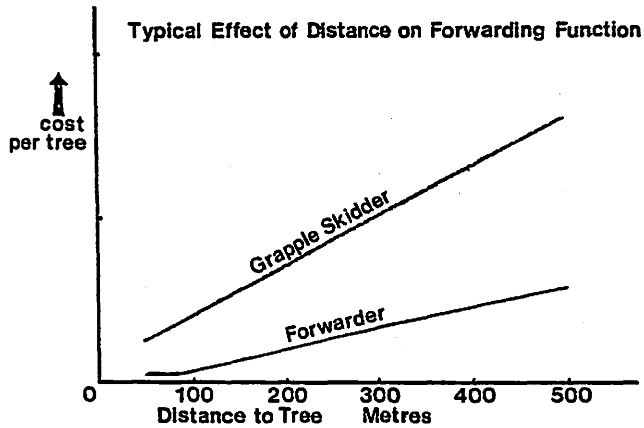
A good way to examine the economics of this sequential multi-function machine is to look at it separately, first, as a feller-buncher, and then, as a self-loading forwarder. The machinery provided can be identified as: that for felling only; that for forwarding only; and that which works at both.

	Felling	Forwarding
Engine	✓	✓
Wheels & Drive	✓	✓
Chassis	✓	✓
Cab & Controls	✓	✓
Boom	✓	✓
Felling Head	✓	—
Bunk	—	✓
Dump	—	✓

As we get into this, we see that there is very little that does not work at both operations; and, even then, the temporarily extraneous components or abilities are sometimes of advantage. For example, the bunk would not be needed if bunches were built on the ground, but, particularly in sparse stands, it assists felling in that the operator always has a place to put his trees.

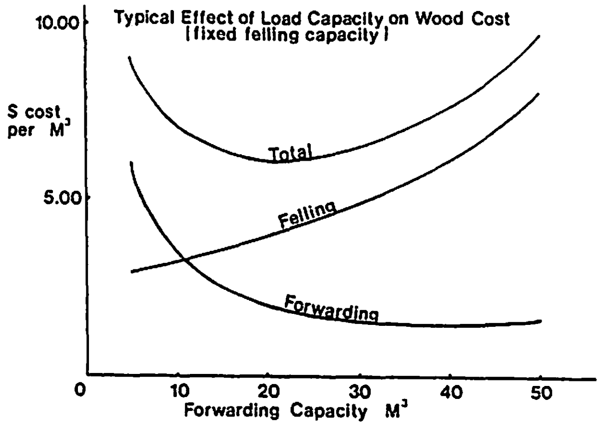
We may question whether felling requires the amount of installed power that forwarding does, but this can be answered by balancing the design: very adequate felling capacity can be used as the guide to horsepower while letting the load size and forwarding speeds follow.

The forwarding functions demand a large machine, not only long enough to hold at least one tree, but with space to take the trees from a long strip and haul them at a low man/day rate. The forwarder should be made of tough components and be physically over-powering in its surroundings. Thus, forwarding stipulations would lead us to a very large machine, stopping only as its components become special and exorbitantly expensive.

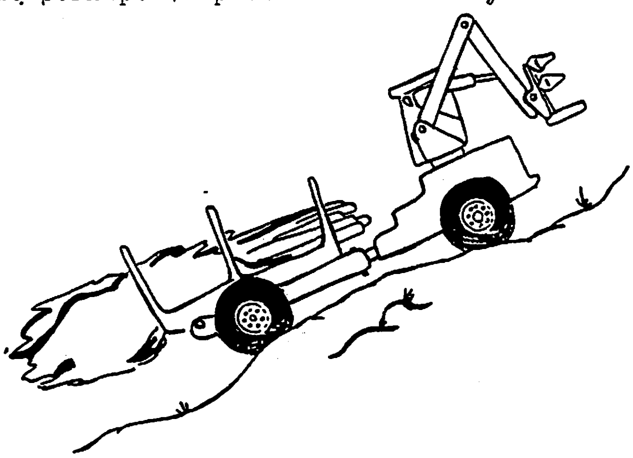


The felling function can often be done by a very small machine, but, as evident in the feller-buncher business, the larger the trees, the more rugged the terrain, and the more we want to help subsequent operations with large well-placed bunches, then the bigger the felling equipment needs to be.

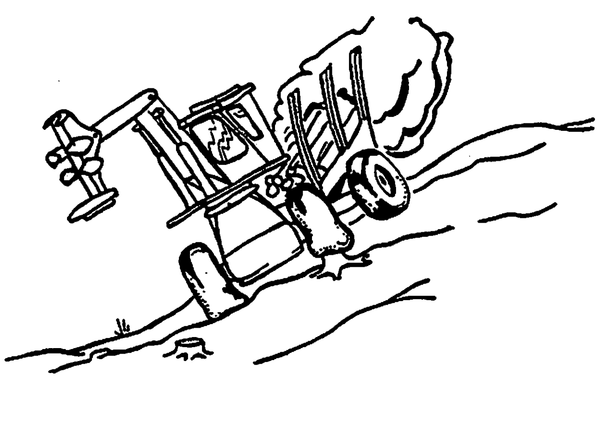
The relative importance of these factors is not easily pinned down, and at this stage we can only observe that the optimum machine size would vary with locations. In addition, small plots and frequent moves often stipulate size to be kept at the minimum that can be made to work. Fortunately, many areas with rough terrain do not have road width restrictions, and to some extent, machine width can be varied to suit at the time of application.

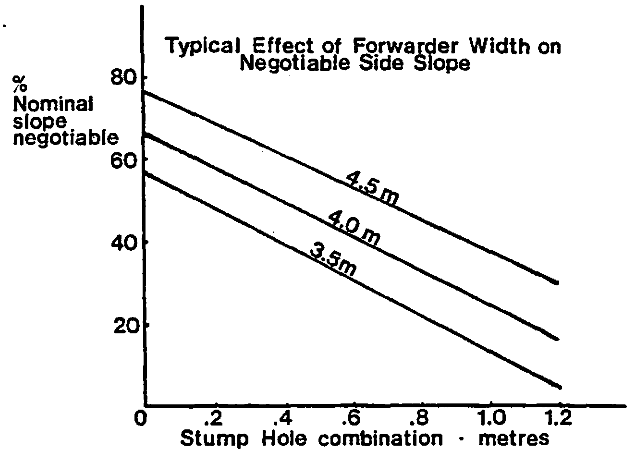


Feller-forwarders handle grades and side slopes better than was proposed at the beginning of their development. The relatively long wheel base helps neutralize short pitches when working up and down grades; and such operation is usually limited by the coefficient of traction on the way up, and the operator discomfort at perhaps 40 percent on the way down.



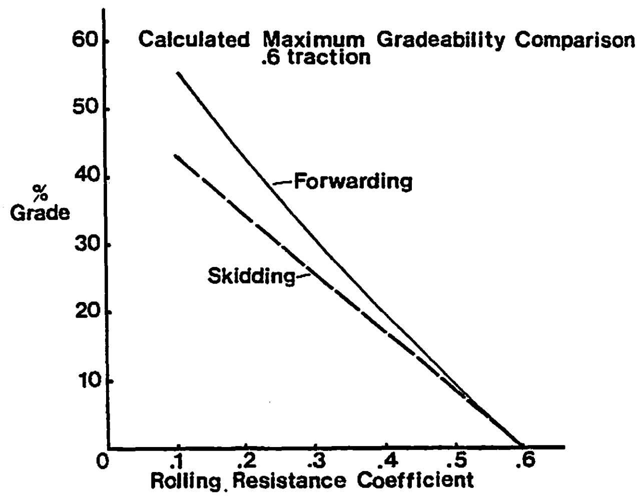
Side slopes are more detrimental to feller-forwarder operation and, for oscillated chassis configurations, what can be handled depends on roughness and how well the machine balance is arranged in the fore and aft direction.





Tailoring wheel base to tree height, reference to stump hole combinations, machine width, and experience are all important in making side slope applications. Of course, just like any other stump area logging machine, feller-forwarders need to be designed to quickly go back to work after taking a tumble.

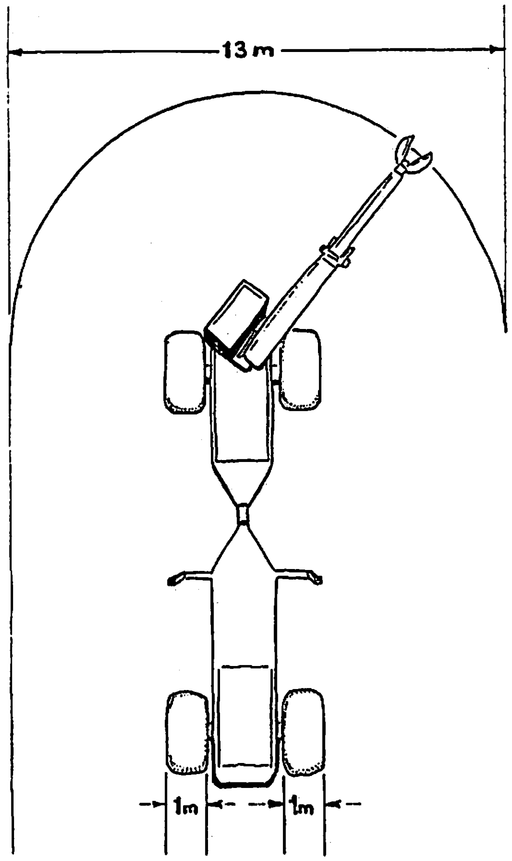
Rolling resistance and flotation are very pertinent to feller-forwarders, especially when we make comparisons with skidder systems.



Since we would like to move the product from stump to roadside with a minimum of energy expended, the load is carried on rubber-tired wheels rather than allowed to partly drag on the ground. The numbers are clearly favourable when making comparisons with grapple skidders.

To be competitive in mobility with other systems, feller-forwarders have relatively large wheels. The large diameter deals more easily with terrain roughness, logs, and stumps. The larger cross section means that the carcass can be made more robust for traction transmission and puncture resistance while achieving ground-conforming contact better than most smaller tires.

A typical feller-forwarder with a 13-metre boom swath width would have a total tire width of two metres, and, except for locations near the road, would travel a given swath area only twice.



The feller-forwarder, with its long-reach boom and easily controlled travel, is mechanically suitable for thinning and sorting operations. Calculations indicate that there will be little productivity loss if at least 200 trees per hectare are taken, and provided the remaining trees are in straight strips, or number 150 or less per hectare.

Work on sorting suggests that the felling head can pick out randomly located trees, sorting for size or species with little productivity loss, provided all trees are taken. Bearing in mind that the felling head has two compartments, simply throwing accumulations to one side or the other can be a good start toward subsequent sorting at the landing. Ideas for separating bunks and clamps have also been proposed.

The product needed affects the viability of feller-forwarders as well. Full-tree chips are the best follow-up. Chipper knives run much longer between changes, almost no limb and top material is lost; if cut, even very small trees always come to roadside, and a large forwarder load equals a trailer load of chips.

If trees are to be delimbed and processed, it is necessary to have mechanized equipment capable of feeding from the large well-packed piles put down by the feller-forwarder. If the forwarder is working close to the delimber, much wood can be concentrated in a small area by continually feeding the delimber with more full trees as it piles its output of delimbed trees.

In most cases, the felling and forwarding is followed by delimbing and bucking.

The recent availability of disc saws has altered feller-forwarder mathematics by allowing a smaller machine to take lumber-size trees, and by theoretically reducing the felling and loading portion of each cycle. The relatively high engine horsepower installed is useable by the disc to sustain rapid tree cutting.

Feller-forwarders are operating mainly in the Canadian boreal forests and in the North Eastern U.S.A. Some operations have also been carried on in the U.S. South East.

Feller-forwarder operators are usually taken from skidder crews, since that is what they are replacing, and they like the concept. Except for serviceing and maintenance, men are not required to work outside of the cab, and it is a comparatively safe job. Man/day productivity is often high: 100 to 200 cubic metres per 8-hour shift. Job satisfaction opportunities are good.

CENTRALIZED TREE PROCESSOR SYSTEM FOR OPTIMIZING THE VALUE OF OUTPUT PRODUCTS[1]

C-G Wachtmeister[2]

INTRODUCTION

Sweden is not well-known for its longwood logging operations. In fact the using of full tree- and stem methods in large scale forestry has dropped from 15 % in 1970 to 1 % in 1982 (Brunberg 1984). The extraordinary development of our logging operations has been undertaken within the shortwood methods. Our shortwood harvestors are now in action over a wide variety of conditions and the performance is high.

There have, however, been serious attempts to question this development. Those who have criticized the massive investments in shortwood systems have the following main reasons to support longwood logging:

1. Longwood logging with central processing makes it possible to handle logs with flexible sorting and highest possible output value.

2. Central processing makes it possible to work in an industrial environment with high rate of production away from difficult terrain- and weather conditions.

3. It is easier to introduce modern equipment such as scanners, computers and robots in a central plant than in mobile systems.

4. Full tree methods utilize valuable forest residues better than shortwood methods.

Approximately 1/3 of the Swedish clear-cut area is located where conditions are suitable for longwood systems. Less than 10 relatively small processing plants are in operation in the southern part of the country. I would like to present some results from four years of operation with a plant built by the Swedish Forest Service. My presentation will focus on how we technically try to optimize the value of each stem.

I also want to put forward a few experiences concerning the marketing and distribution of lumber further down the market channel.

LOGGING SYSTEM AND MARKET CONDITIONS

The plant is located in the centre of a forest district with an annual clear-cut volume of 140 000 m^3s[3)]. Pine and spruce account for 95 % and the medium stem volume is 0.40 m^3s. The trees are felled, logmadelimbed and transported 35 km to the plant. Our maximum net truck load is restricted to 32 m^3s.

1) Paper presented at the IUFRO Conference - 1984. Fredericton, N. B. Canada.

2) C-G Wachtmeister is research assistant at Linköping Institute of Technology. S-581 83 Linköping, Sweden.

3) m^3s = solid wood under bark.

The organization of the work at the plant is built on a high degree of self-supervising. It is of great importance that close contact is established between the logging units, the plant and the marketing of the produced products. To a certain extent we try to let the demand of logs direct the selection of logging areas so that species and tree-size suit current markets.

The idea of this plant is to meet and extend the demand of custom-made deliveries to the saw-mill industry in the area. Pulpwood and special assortments (veneers, poles, sleepers) are sold to various customers. In figure 1 are shown the principles of shortwood and central processing systems.

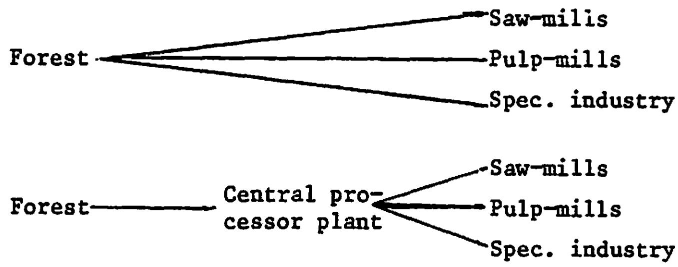


Figure 1. -- Principles of shortwood and longwood systems.

The plant is located in an area in the south with a heavy concentration of wood processing companies. Within 35 miles there are 50 mills and approximately half of the Swedish prefab-house capacity. The mills have to a great extent specialized their production, and they have in many cases found profitable market shares. Accordingly the demand for sawlogs in the area is high and differentiated. We account for about 10 % of our customers' requirements.

The saw-mills can order logs from the plant which suit the demand of their lumber customers. The possibilities to produce these specified logs are restricted only by plant productivity and forest conditions (quality, volume, species). Two examples of specifications from our saw-mill customers are shown in table 1.

Table 1. -- Two types of specifications from saw-mill.

	Specification easiest to meet	Specification more difficult to meet
Type	Sawlogs, spruce	Sawlogs, pine
Quality	V or better	Max 40 % VI, remainder V
Length	49 dm	30 %, 31 dm 40 %, 36 dm 30 %, 45 dm
Top diameter	16-21 cm (ub)	14-15,9 cm (ub)
Quantity	1 000 m^3	500 logs
Delivery time	As produced during season	1 month

In these cases the saw-mill has taken advantage of the possibilities concerning the quality, the diameter, the length and the delivery time of its raw material. The delivery time is not the least essential as direct trucking of lumber to customers in Europe is frequently used nowadays.

THE HJÄLTEVAD PLANT

Now back to our plant. It consists of three main sections:

- feeding table
- scanning and bucking section
- sorting line.

The duty of the operator at the feeding table is to keep the plant supplied with fault-free timber stems. Using a grapple saw he can, for instance, cut off decayed portions and larger root buttresses. Small diameter or decayed pulpwood stems can be sorted out at the feeding table and handled in a separate bundle cutter.

Lengths and diameters are measured automatically in the scanner. The accuracy is as high as that obtained in wood value measurement of logs, namely ± 2 mm in diameter and ± 15 mm in length. The conveyor moves at a speed of 60 m/min, and the average length of the stems is 16 m.

The bucking process is controlled and monitored by two operators who releive each other in 2 hour periods. The operator determines the quality of the stem in the bucking section. As it moves transversely towards the operator the stem can be made to roll to allow examination of the whole of its outside surface.

In order to mark the length of the measured, but not yet cross-cut stem, there is a row of lamps. As the operator looks for the quality limits the lamps light up above it. In our plant crooked stems are best observed from the root end in a mirror.

The operator can either decide what each stem will yield by combining length- and diameter values, presented in front of him, or confine the decision to the electronic optimizing equipment. More of this later.

Cross-cutting by two saws, and subsequent sorting, is controlled by a process computer. Position of the cutting point is controlled by slowing down the conveyor from 60 m/min to 6 m/min just before the predetermined length is reached, at which point the conveyor stops. A photocell starts a pulse counter by means of which the trimming allowance can be varied. The sorting line allows sorting into 18 pockets. The logs are then placed in stacks, one for each customer.

The plant is served by a 17 ton high-lift truck which unloads the incoming trailers and empties the sorting pockets. The production capacity of the plant, operating on one shift, is 250 000 stems per year or 75 000 m^3s.

Operating experiences

The cross-cutting accuracy - which in the beginning was not quite satisfying - has now stabilized at ± 10 mm after complementary installations. The mechanical breakdown time of the plant is 20 %.

When designing the bucking section, where the main value is produced, the following should be kept in mind. The operator must sit close to the stem - not further than one metre away. While a close view is needed for judgement of quality he must also have a certain perspective view of the stem in order to see crooked ones properly, if these are not observed in any other way. We have not yet found a satisfactory answer to the problem of these two opposing requirements. The lighting in this section of the plant must be uniform and without reflections. A perfect environment would, therefore, involve carrying out this work indoors, with the operator able to move freely along the length of the stem.

The technical design of the plant has not limited flexibility of operation. On the contrary, we can commence production of a special size or quality the moment an order is received. Information is routed quickly to very few people, a foreman and an operator in fact, and this is where the strength och the central processing lies.

Product output

The system has now been in operation for four years. During this time we have closely followed output of production and prices. It is of interest to what extent the customers have utilized the possibilities to order custom-made sawlogs, and if the central processing system is profitable to the forest owner. It is natural to compare central processing output to those volumes produced from the forest district with other logging methods, i. e. manual chainsaw- and mechanized shortwood systems.

The revenue from logging of coniferous forests is highly dependant on how flexibly different assortments can be produced. From figure 2 we can learn that during a period before the plant was built the same forest district produced 3/4 of the volume as bulk-sawlogs. The rest was delivered as pulpwood and special assortments. During the period after the plant was taken into operation the mobile systems have produced less sawlogs and more special assortments. The installation of the central processing system has in fact partly influenced operators and supervisors of the other logging systems to produce products of a higher value.

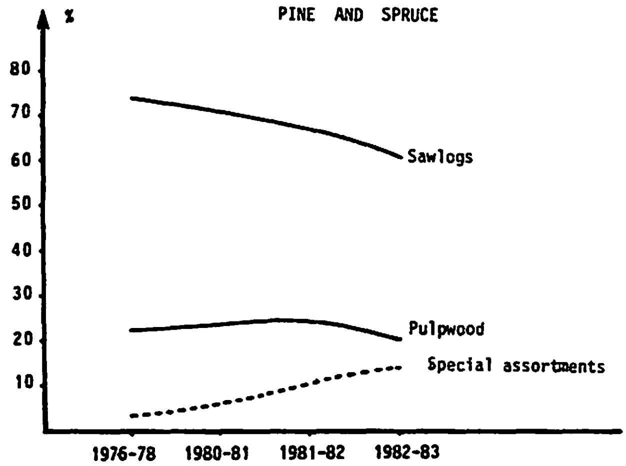


Figure 2. -- Product output from sorting in forest logging, 1976 - 1983.

The product output from the plant has developed with the changing demand for specifications. Figures 3 and 4 show product output for pine and spruce respectively. Bulk-sawlog volumes have dropped to 1/4 of total volume, and they have been replaced by specifications. The demand for these products has been steady and rising. At present (spring 1984) they account for about 50 % of total output. Specifications of spruce are more frequent than of pine because end-users in the building industry can easier utilize special lengths of spruce. The local industry for poles, veneers and sleepers has been ablo to order raw material in bigger lots and with easier access than at forest roadside. The differences in pulpwood output over the years are due to fluctuations in price and decayed sprucewood (delivered as pine pulpwood).

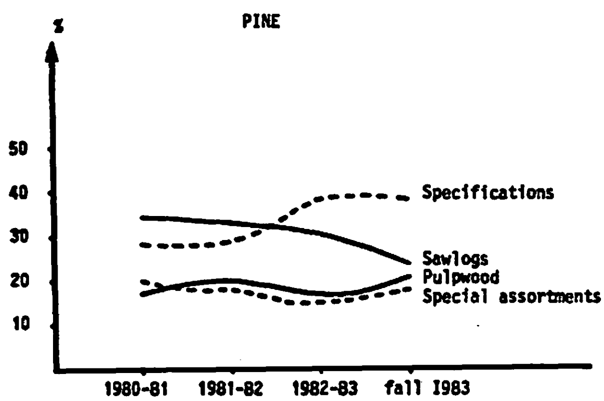


Figure 3. -- Product output from central processing, pine.

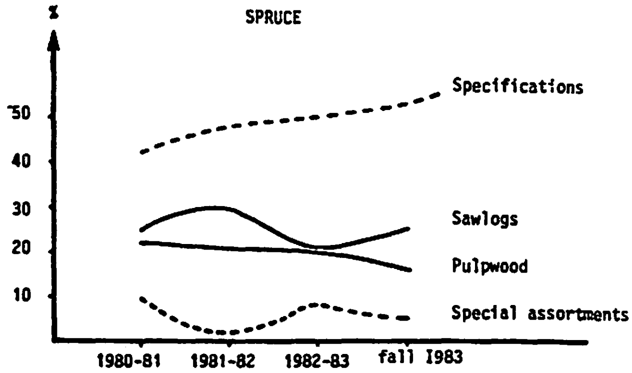


Figure 4. -- Product output from central processing, spruce.

One question of interest can now be risen. Has the "picking out" of specifications influenced the value of bulk-sawlogs so that the total value is equal to or lower than without specifications? Our analysis shows only one significant difference in value-setting factors, namely the diameter distribution of sprucelogs. Figure 5 shows that the "picking out" of specifications has been more frequent in middle diameter classes which means that output of small and big bulk-logs is slightly higher than in normal logging. The value of this deviation has only a marginal negative effect on total output value.

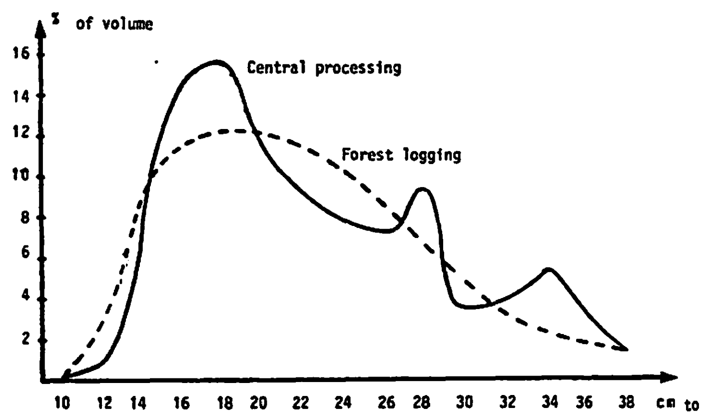


Figure 5. -- Diameter distribution of sawlogs from central processing and forest logging, 1982 - 1983.

Is central processing beneficial?

Of course, this question cannot be answered in general. An easy way out would be to list the advantages and disadvantages of longwood and shortwood logging without talking of econimic results. I want to try the other way.

In Sweden there are two different situations in which central processing is used:

1. Forest owner operated plant with diversified product output.

2. Saw-mill integrated plants.

The Hjältevad Plant described above belongs to the first category.

All other longwood systems (about five) are built in integration with saw-mills. One of these plants, with a similar annual production to Hjältevad, is described in literature (Eliasson 1983). Full tree systems with processing at upper landing or at a central plant have been comparatively analysed at Skogsarbeten (Jonsson 1982).

Regardless of market situation or owner objectives it is a fact that central processing systems, working with one tree at a time, need

- large coniferous trees, > 0.30 m^3s and
- short transportation distances, < 50 km

to economically compete with shortwood harvestor systems.

In the Hjältevad case we have compared the economic result with that from the forest logging operations of the same district. It is important to observe that the volumes delivered at roadside in this case are paid with comparatively high prices due to large volumes and intensive marketing. The economic output shows a small deficit of about CAD 0.75/m^3 during the first years of operation and a zero result at present times. Our experience is that the system is more profitable to the forest owner during lumber market depression times because saw-mills then need to specify their products better. We have also found that many saw-mills have an inadequate knowledge of the end-use market of lumber, due to a complicated distribution system.

If a co-operative of forest owners would set up a system similar to Hjältevad (as in a few cases in Norway and W Germany), and use its advantages properly, the system would be profitable if compared to today's logging forms and log prices.

In the above mentioned report (Eliasson 1983) from a saw-mill integrated central processing operation, stems have been processed for nearly 20 years. The main issue of the report is to calculate the economic result of full tree processing. The full tree system is estimated to be profitable under current conditions as compared to mechanized harvesting. The author points out that costs for log handling and inventories can be reduced when the plant is integrated with the mill.

The residues (about 20 % of stemvolume) are calculated at a zero result which means that the revenue comes from a better utilization of saw logs. This value, obtained by central processing, is divided into three categories:

1. High technical precision (cross-cutting accuracy, elimination of crooks).

2. Optimization of raw materials.

3. Integration values through flexibility to market conditions.

In his analysis, Jonsson (Jonsson 1982) states that full tree logging with central processing costs about 60 % more than if the processing is done at the upper landing. For the conditions used in the analysis it is unlikely that higher wood output value would cover these costs. Jonsson discusses a combination of shortwood and longwood methods in which a shortwood harvestor processes the small trees beforehand so that the plant only handles the valuable trees. In the Swedish Forest Service we have made promising studies of this idea, and we expect to generate more results this year.

Optimized sorting

Compared to mobile systems central processing plants can utilize modern electronic equipment more effectively. It is primarily due to the fact that the computer receives correct data from the entire stem and not only an estimation of taper etcetera. In Hjältevad we are faced with an extremely diversified production with over 50 possible assortments to combine for highest possible output. Regardless of how skilled the operators are it is impossible to beat a computerized calculation as a means of improving the sorting.

Our program has not yet been in regular operation due to technical difficulties. It is based on linear programming and uses a specific logic to minimize the processing time. When the maximum alternative is calculated it is presented to the operator on a monitor and by the lamp row above the stem. Thereafter a pocket-search program destinates the different assortments. As specifications sometimes overleap each other we have a system of priority where the delivery time of each specification influences the sorting. If two specifications have the same delivery time (time left to contract deadline) and volume they will be chosen every other time.

In our tests of the economical output of the optimization equipment we have found that in comparison with our extremely skilled operators it increases the total wood value by 2 - 4 %. However, the electronic equipment can in no way replace the operators. We regard it as a complementary support.

It is especially suited for "difficult" stems where the calculation of the cutting points is tedious for the operators. In difficult and rare situations, e. g. large pines of high quality, the program is slower than the operator to come up with an acceptable solution.

2 - 4 % does not sound so much, but it means in fact that such equipment, with our production capacity, has a pay-off time of less than a year.

DISCUSSION

It is a fact that the development of logging equipment in the 60-ies and 70-ies to a great extent has been focused on the pulpwood assortment. This means that we have developed shortwood machines which in the same operation and with the same speed have processed the tree into sawlogs and pulpwood. The pulpwood, being the low-value assortment of the two, has therefore forced the productivity with suboptimal results for the sawlogs.

Today new and cheaper methods are developed such as tree-section logging (bucked tree-sections with limbs on) for the pulpwood- and energy-fraction of the tree. Various concepts of bundle-delimbing of small trees and tree-sections are tested today. This development is interesting, but dependant on the pulpwood industry and its flexibility to handle trees. Restrictions on full tree methods are introduced today in certain areas because of biological reasons.

In 1982 the shortwood harvestors accounted for 21 % of the final felling volume in large scale forestry. This method is predicted to increase its efficiency by 3.5 % per year and account for over 50 % of the volume in 1990 (Ericson and Rådström 1984). The recently introduced one-grip harvestors have captured the minds of many production-oriented forestors. Unfortunately these machines are not as suitable as the traditional two-grip harvestors concerning the treatment of wood value. One-grip harvestors are extremely efficient in thinning operations but should at present not be used in stands where sawlogs are produced. The development of equipment to improve output value on mobile machines has for the moment stopped. Let us hope temporarily.

This line of development ought to bring new solutions to the logging of sawlog assortments.

In this work we have to carefully penetrate where and how the crosscutting should be done. A better definition of forest stand population with respect to quality and size is a primary condition. It should be possible to correctly determine the stem form (taper, crook) and quality. The development of X-ray or computed-tomography equipment for this purpose is interesting, but at present only suited for research purposes. Precise cutting with flexible allowance must also be possible.

It is obvious that longwood methods and central processing have lost all practical importance in Sweden. The economic results have not been good enough to convince forestors and machine manufacturers. It has been much easier to develop equipment to increase productivity rather than product value.

Another factor is that the saw-mill industry has not forced forestry to produce specified and high quality logs. Competition for sawlogs has been too strong to raise questions about product quality and length specification. The saw-mill structure is, however, changing, and there are already areas where mills do not have to buy every log produced. If this development continues there is a value for the future in the alternative logging systems.

We must not proclaim that central processing is the only solution to increase forest product value, but it is a valuable and future-oriented method to develop further. Therefore it is necessary to build new plants and to document and discuss their results.

LITERATURE CITED

Brunberg, Torbjörn. 1984. Result nr 8, Skogsarbeten. Stockholm.

Eliasson, Mikael. 1983. Central processing of full trees with sawmill integration. Rapport NE/SBT-83/23. Nämnden för energiproduktionsforskning. English summary. Stockholm.

Ericson and Rådström. 1984. Svenskt storskogsbruk 1982 och 1990. Redogörelse Nr 2, Skogsarbeten. Stockholm.

Jonsson, Yngve. 1982. A comparative analysis of full-tree systems in final felling. Redogörelse Nr 4, Skogsarbeten. English summary. Stockholm.

RATIONALIZATION OF WOOD DELIVERY BY ROAD, RAILWAY AND WATER IN SOUTH-EASTERN FINLAND[1]

Reino E. Pulkki[2]

Abstract. A paper briefly outlining a project dealing with the coordination of wood procurement and water transport. Factors which had to be taken into account are covered. A heuristic simulation system used for aiding long-distance transport decision-making is also introduced.

INTRODUCTION

This paper briefly outlines a project currently in progress dealing with the coordination of the variations in wood procurement and water transport. As viewed from the firm, wood procurement begins with wood purchasing and ends with delivery of the wood to the mill. Millyard handling and inventories can also be held as a part of wood procurement. Wood can be purchased as standing trees, at roadside or delivered to the mill. When viewed by a Finnish firm, the wood procurement courses of action open to it are shown in figure 1. The courses of action open to the forest owner, whether State or private, are presented in figure 2. During the 1982-83 harvesting year the distribution of all industrial cuttings was as follows: stumpage sales from private forests 52.8 %; delivery sales from private forests 26.2 %; company forests 9.0 %; and State forests 12.0 %. Almost all wood harvested from State forests was by the delivery sale method; 95 % during the years of 1982 and 1983.

What do we mean by rationalization? Hakkarainen (1978) states that rationalization is orderly and continuous development meant to increase productivity and to make work more meaningful. It is achieved through scientific and technical means. Rationalization helps in keeping pace with development, adapt to changes in the environment and means orderly development of operations.

Long-distance transport is limited in the study to cover the transport of wood raw material from the forest, at roadside, to its place of utilization. It includes all possible combinations of transport methods irrespective of the distance, and includes all terminal operations and intermediate storages. Extended primary transport from the forest to a long-distance transport terminal or directly to the mill is also held as long-distance transport. Long-distance transport can also include the transport of finished products to the market, however as apparent from above, it is not included in the study. The possible combinations of long-distance transport methods available in south-eastern Finland are also presented in figures 1 and 2. In the study initial transport to the water or railway network and terminal operations are included in water and railway transport.

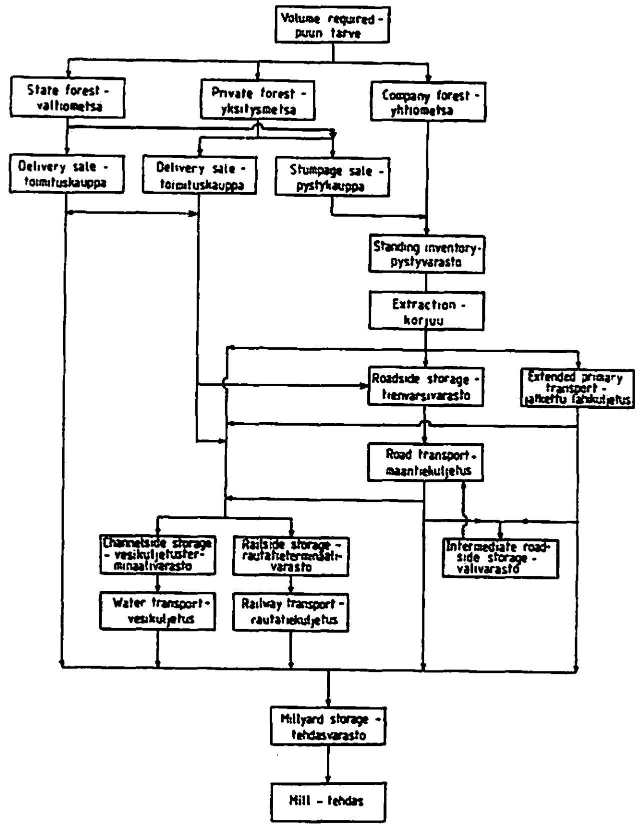


Fig. 1. Wood procurement courses of action open to a wood purchaser in Finland.

The study is limited to the Vuoksi, Jänisjoki, Kiteenjoki-Tohmajoki and Hiitolanjoki watersheds and is referred to as the Saimaa area. The Saimaa area is very similar to the south-eastern Finland wood procurement area, with the exception that the latter area follows municipal and not watershed boundaries. The total area of the Saimaa area is 56 075 km^2, while that of the south-eastern Finland

[1]Paper presented at the joint conference COFE/IUFRO - 1984. Fredericton, New Brunswick, Canada, August 17.

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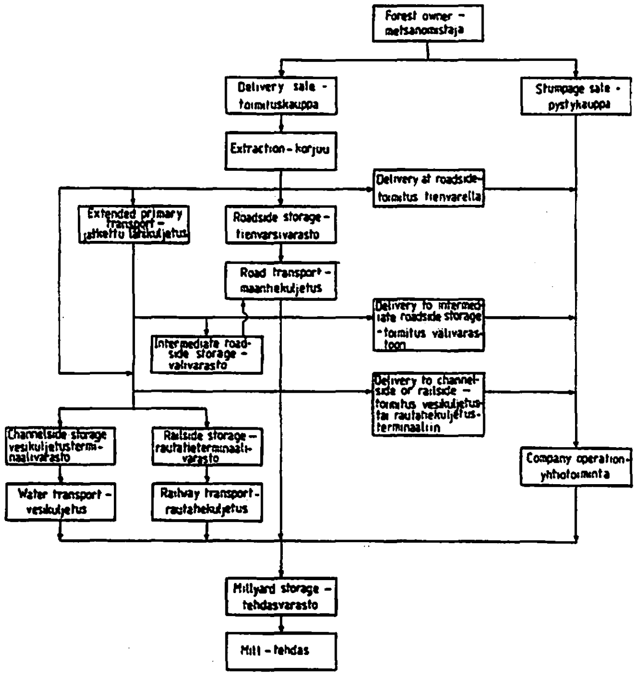

Fig. 2. Courses of action open to a wood seller in Finland.

wood procurement area is 56 490 km^2. Although this paper deals with south-eastern Finland, the Saimaa area, which is the area under study, can be held as being more or less the same area.

The purpose of the study is to develop a system which can be used in solving transport problems and in formulating transport policies in an ever-changing environment. Since we have seasonal and multi-year cyclical variations, combined with developments in the forest industry, transport networks, harvesting techniques and the forest itself, we see we have a very complex problem. The problem is further aggrevated when you have many different wood purchasers with plants at many locations competing for the same wood and a very large number of wood sellers: for example, there are more than 340 000 private and company forest holdings in Finland, with the average size being about 48 ha. If only private forest owners are taken into account the average size is about 33 ha. Since there are so many variables which must be accounted for, it is inconceivable to use linear programming or other such related operations research methods. Due to this, a heuristic simulation system had to be developed. A set of models were formed of the transportation environment in the area. The models were tested and then used to mimic (i.e. simulate) wood transport in the area. The results were used as a heuristic tool to stimulate further discussion and finally to aid in decision-making. Simulation itself is not an optimization tool. However, information gained through simulation can be used in optimization models. In the study we are striving to minimize the cost of wood procurement in a dynamic environment, while also accounting for its impact on the wood processing costs and product yield.

FOREST INDUSTRY IN THE AREA

In the area we have a wood industry ranging from small portable sawmills using a few hundred m^3 of wood for domestic use, to large integrated wood processing complexes capable of using in excess of 2 M(m^3)/a. If sawmills using in excess of 5 000 m^3/a are only accounted for, we find that there were 40 sawmills in operation in the area in 1983. There were also 19 wood-based panel mills (13 plywood, 5 chipboard and 1 particle board mills) and 10 pulp and/or paper mills in operation in the area. Wood processing mill locations are shown in figure 3. In all, we can locate 37 separate wood processing centres/points requiring various volumes of wood. Wood volumes used by the forest industry in the area since 1979 are shown in table 1. The majority (57 %) of the centres/points use less than 100 000 m^3/a. The mills in the area account for about 25 % of industrial wood consumption in Finland. During a peak year, total annual consumption of industrial roundwood and forest chips is now slightly greater than 13 M(m^3). Mill residues are also used to a large extent but are not included in the study.

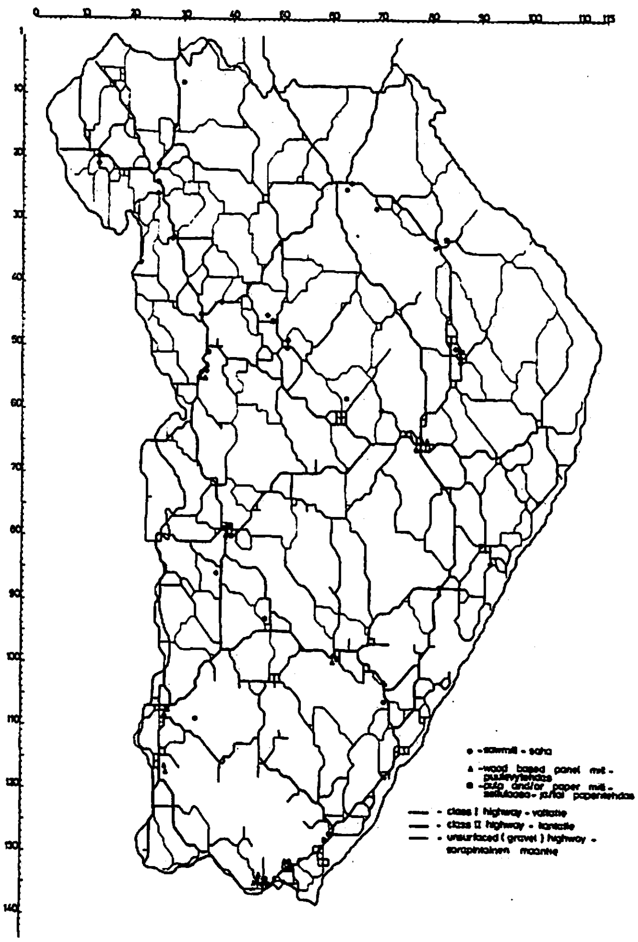

Fig. 3. Major road network in south-eastern Finland and mill locations.

Note: - m^3 is solid volume, bark included
- M(m^3) is mega (million) cubic metres

Table 1. Volumes of wood delivered to mills in south-eastern Finland by wood assortments (includes imported[1] wood).

Year	Mill delivered wood volume, (1000) m^3						
	Soft-wood logs	Hard-wood logs	Other soft-wood	Other hard-wood	Forest chips	Indus-trial residue	Total
1982	3 752	692	3 297	1 742	787	1 351	11 621
1981	4 130	805	3 293	2 618	192	1 186	12 224
1980	5 063	834	3 422	2 449	39	1 699	13 506
1979	4 800	684	2 896	2 170	37	1 319	11 906

[1]Volume of imported wood in 1982 was 1.296 $M(m^3)$.

WOOD PROCUREMENT CHARACTERISTICS

The total land area in south-eastern Finland is 45 243 km^2 and the lake coverage is 19.9 %. From the 7th national forest inventory (Kuusela and Salminen 1983, Uusitalo 1983), the annual allowable drain for the area can be estimated to be about 15 $M(m^3)$. Total drain (industrial, fuelwood and domestic consumption, wood export, logging residues, floating losses, and mortality) in the area during 1981 was 13.88 $M(m^3)$ (Huttunen 1983).

In Finland, 98 % of the volume logged is by the shortwood method (Salminen 1983). In the shortwood method the various wood assortments are cut in the stump area and in most cases a forwarder is used for forest (primary) transport. The use of agricultural tractors is more or less restricted to farmers who harvest their own wood and sell by the delivery sale method. Forwarders account for about 88 % of forest transport, while agricultural tractors and skidders account for about 10 % and 2 %, respectively (Vesikallio 1981). At the end of 1981 about 20 % of the annual volume harvested by companies and the State was by mechanical means; about 16 % of the total harvested volume (Vesikallio 1981).

The average composition of wood costs by wood assortments delivered to the mill in south-eastern Finland is presented in figure 4. Stumpage forms the major part of the wood cost at the mill for logs, while extraction and long-distance transport form the major part for pulpwood. The average stumpage rates for the area during the 1982-83 harvesting year were as follows:

- pine logs	- 160.81 FIM/m^3
- spruce logs	- 131.34 "
- hardwood logs	- 153.45 "
- pine pulpwood	- 78.52 "
- spruce pulpwood	- 78.01 "
- hardwood pulpwood	- 60.46 "

Note: - 4.40 FIM equals about 1.00 CAD
- 1.00 FIM equals 100 p

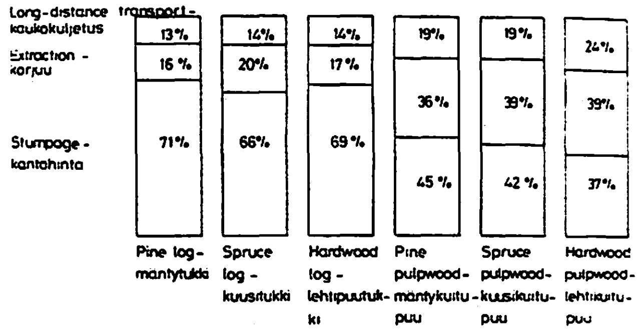

Fig. 4. Average composition of wood costs by wood assortments delivered to the mill in south-eastern Finland.

LONG-DISTANCE TRANSPORT INFORMATION

Table 2 presents the volumes delivered to mills in south-eastern Finland from 1972 to 1982. As can be seen, the variations in the volume of wood delivered to mills in the area have been quite large in past years. This is due to market conditions, with cycle peaks occurring during 1974 and 1980. The largest change between successive years occurred between 1974 and 1975; a reduction of 6 $M(m^3)$ or 38 % from the volume delivered during the preceding year. Also apparent is that the volume delivered by tractor has decreased steadily and is more or less insignificant in the area today. The volume delivered by water transport has remained fairly steady and the annual variations in total wood requirements have not had too much effect; the coefficient of variation (CV) is only 7 %, compared to 30 % for both truck and railway transport. The variation in railway transport is due to the combined effect of annual wood requirement variations and tariff policies; if the tariff schedule overly increases compared to the other methods, wood is easily transferred to truck transport. Truck transport seems to be the method which picks up or looses wood most readily, with changes in wood requirements.

The average transport distances and average direct transport costs for the long-distance transport methods available are presented in table 3. The values given in table 3 do not include initial transport to railway or water transport terminals. The per cent and absolute cost increases in average direct transport costs, excluding initial transport to the terminals, from 1972 to 1982 were as follows:

- tractor transport	- 18.2 %/a	116.4 p/(m^3·km)
- truck "	- 10.9 "	22.8 "
- railway "	- 11.5 "	6.9 "
- water "	- 11.6 "	4.8 "
- wholesale price index	- 12.8	

When transport distance is also accounted for we obtain the transport output. Since the average transport distance is longer for both water and railway transport, their share of the transport output is larger than for mill delivered volume. During 1982, the shares of transport output for truck, railway and water transport in the area can

Table 2. Volumes of wood delivered to mills by transport method.

Year	Tractor		Truck		Railway		Water		Total	
	1000 m^3	%	1000 m^3	%	1000 m^3	%	1000 m^3	%	1000 m^3	%
1982	2	0	5 761	50	1 340	11	4 518	39	11 621	100
1981	3	0	6 202	51	1 742	14	4 277	35	12 224	100
1980	31	0	6 689	50	2 264	17	4 522	33	13 506	100
1979	25	0	5 685	48	1 764	15	4 432	37	11 906	100
1978	26	0	4 406	47	1 155	12	3 896	41	9 483	100
1977	35	0	4 004	40	1 663	16	4 430	44	10 132	100
1976	43	0	3 368	35	2 338	24	3 899	41	9 648	100
1975	79	1	3 413	35	2 066	21	4 246	43	9 804	100
1974	122	1	8 306	52	2 623	17	4 778	30	15 829	100
1973	259	2	4 880	42	1 447	13	4 896	43	11 482	100
1972	210	2	3 936	41	915	10	4 514	47	9 581	100
$\bar{x}$	78		5 150		1 756		4 401		11 383	
s(+/-)	86		1 540		528		312		1 981	
CV		110		30		30		7		17

be calculated to be 23, 22 and 55 %, respectively. For the country as a whole the corresponding values were 46, 21 and 33 %.

In water and railway transport, initial transport by truck or tractor is required in almost all cases. In south-eastern Finland the average minimum distance to a water transport terminal is 25 km, while to a railway terminal it is 26 km. There are 88 water transport and 88 railway transport terminals servicing the area. Figures 3, 5 and 6 present road, water and railway transport networks and infrastructure available.

Inland waterway channels are classified into four classes:

- Is deep channels depth ≥ 4.2 m
- IIs main channels 2.4 m ≤ depth < 4.2 m
- IIIs side channels depth < 2.4 m
- IVs floating channels specified under floating regulations for each watershed but unmarked on inland waterway maps

The shallowest marked channel can be held to be 1.2 m in most cases. All channels have a 0.6 m safety margin, which can be added to the above values to get the actual channel depth. The channel depth in inland waterways is measured from the lowest water level during the navigation season (NW_{nav}). The minimum water depth required in bundle floating is 3.0 m. However, a depth of 2.5 m is generally sufficient in the upper reaches of the waterway. Of all marked inland channels in Finland, 48 % lie in the Saimaa area, while the corresponding value for all inland channels is 35 %. The distribution of channels by classes in the Saimaa area is as follows (TVH 1979):

- Is (≥ 4.2 m) 755.4 km
- IIs (2.4 - 4.1 m) 1 123.1 km
- IIIs (0.0 - 2.3 m) 1 036.7 km
- total marked channels 2 915.2 km
- IVs (0.0 m -) 317.9 km
- total channel length 3 233.1 km

Table 3. Average long-distance transport distances and average direct transport costs[1] in Finland.

Year	Tractor		Truck		Railway		Water	
	km	p/(m^3·km)	km	p/(m^3·km)	km	p/(m^3·km)	km	p/(m^3·km)
1982	10	143.2	74	35.3	297	10.4	226	7.2
1981	13	101.7	75	34.2	289	9.7	249	6.5
1980	17	64.2	81	26.1	225	10.1	253	6.6
1979	14	75.5	84	23.0	246	9.0	236	5.0
1978	21	51.3	88	19.7	248	7.4	239	4.5
1977	16	48.7	81	20.2	250	7.2	231	4.7
1976	19	61.1	82	19.5	232	6.9	249	4.3
1975	16	66.2	72	19.8	178	7.3	243	4.2
1974	17	46.3	71	16.9	174	5.6	205	2.8
1973	18	34.8	67	14.0	237	3.6	211	2.8
1972	22	26.8	64	12.5	214	3.5	209	2.4

[1] The direct costs for railway and water transport do not include initial transport to terminals.

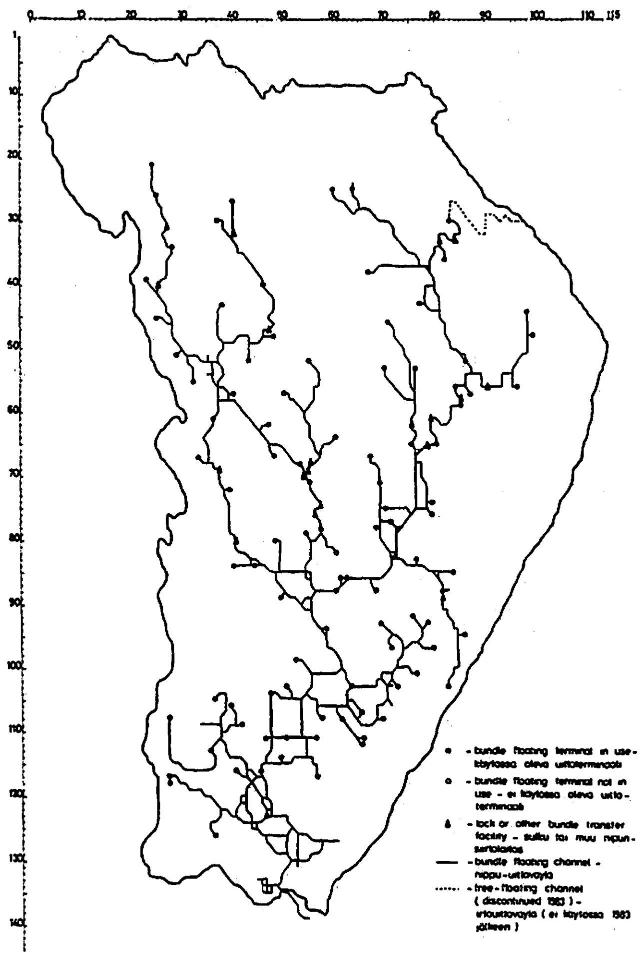

Fig. 5. Water transport network in south-eastern Finland.

The total length of mainline railway servicing the area is about 1 400 km. The length of public roads in the area in 1982 was 14 531 km (TVL 1983). Unfortunately, an accurate estimate of the length

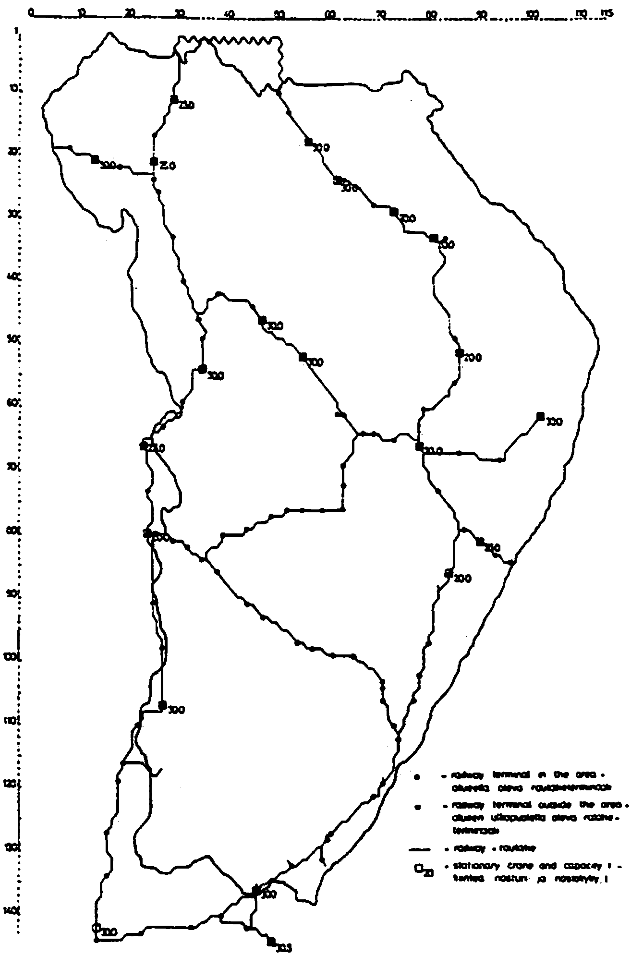

Fig. 6. Railway transport network in south-eastern Finland.

of private roads in Finland today is lacking. Wiiala (1962) estimated that there were 375 000 km of private roads in Finland in 1961. If we add to this forest roads built since 1961 (about 75 000 km), we obtain a private road estimate of 450 000 km. If we assume that about 20 % of private roads have been built in south-eastern Finland, since 20 % of public roads lie in the area, we can estimate that the total road length is about 105 000 km. This gives us a road density of 23 m/ha. Wiiala (1962) stated that the average road density in Finland in 1961 varied from 10 to 30 m/ha, with public roads forming 10 to 15 % of all roads. Calculated from above we get the share of public roads in the area to be 12.6 %.

From the above we can see that the area is well serviced by all three transport methods. For wood harvested in the area, truck transport is used mainly for road distances from 4 to 120 km. With present tractor payment rates, extended primary transport should not be used for distances greater than 5 to 8 km, depending on wood assortment. Depending upon wood assortment and time delay factors (e.g. interest cost), bundle floating in the area begins to be competitive with truck transport once a truck transport distance of 40 km is reached. This exceptionally short distance is due to the dense water transport network in proximity of the larger wood using centres. On the other hand, small sawmills rely only on road transport. Vesikallio and Salminen (1978) state that in Finland on average, the transport of logs by truck transport and water transport compete with one another over distances of 90 to 200 km, after which floating is cheapest in all cases. For pulpwood the corresponding distances are 60 to 120 km, after which floating is cheapest.

In south-eastern Finland, railway transport is not used to as great an extent as truck or water transport to delivery wood harvested in the area to mills in the area. Of railway delivered wood, 25 % was imported wood (mainly from the Soviet Union) and 30 % was from other watershed areas. Similarly, of wood dispatched from railway terminals in the area, the majority (64 %) was transported to mills outside the Saimaa area. In the area, railway transport cannot compete with truck transport in any situation where the road distance is less than 130 km. Railway transport is more expensive than water transport in all cases.

FACTORS AFFECTING LONG-DISTANCE TRANSPORT POLICY

General

When choosing the optimum employment of transport methods, a firm wants to achieve the best overall economic result over the long-term. The inventory policy has a direct effect on the transport methods applicable. For example, if a firm wants to take a large risk of running out of wood, but keep holding costs at a minimum, it would choose minimum inventories and thus hot-logging techniques; for which road transport is most appropriate. In any decision on the most appropriate inventory the following factors must be accounted for:

1) holding costs
   - i) interest costs
   - ii) storage costs
   - iii) handling costs
   - iv) insurance cost
   - v) depreciation/deterioration cost
2) set-up costs or ordering costs
3) shortage or penalty costs
4) production costs and purchase prices
5) lead-time (e.g. for raw materials the period between order and arrival)

Unfortunately, in past years too much attention has been focused on on interest costs alone and thus the favouring of minimum inventories and hot-logging techniques. As will become apparent, hot-logging techniques are only applicable where we have certainty in wood procurement.

Although it is best to view the available transport methods as forming an integrated transport system, it is also beneficial to view the methods as competitors. In this way competition is stimulated between the methods and thus costs are kept better in line. If one method becomes more competitive, the others must follow suit or loose their share of the transport volume. When deciding on the most appropriate share of transport methods we have both business economic and national economic factors which must be taken into account.

Business economic factors

Since private forests form the major source of wood used by the forest industry, the timing when wood becomes available is an important factor. Most wood sales occur during the fall and it is difficult to predict how wood sales will develop in the next harvesting year. This is the case today where the industry requirements are much larger than the volume of wood coming up for sale. Wood shortages at the mill are common at many Finnish mills today. The problem of stimulating the desire of private forest owners to sell wood is under serious scrutiny nowadays. A general observation has been that companies which have resorted to the use of minimal inventories have been the ones most susceptible to wood shortages; excluding mills with small wood requirements. Mills which have relied largely on water transport and thus larger inventories, have been able to draw on wood stored in water storages. Living hand to mouth also results in transport without regard to cost, since wood must be transported directly to the mill once it becomes available.

Although in past years there has been an attempt to schedule harvesting operations uniformly throughout the year, 68 % of commercial cuttings still occurred during November to April in the 1982-83 harvesting year: i.e. during the winter season. During the 1981-82 harvesting year the corresponding value was 63 %. The spring break-up period in April-May also has its effect on uniform wood supply. Also, wood must not be stored in the forest during late spring and summer due to insect damage directly to the wood and to surrounding stands, and damage due to blue stain fungi. If wood must be stored, water storage is generally held as the best method. Also, due to the above variations in wood supply, the difference between average size of inventory required for 100 % road transport and, for example a 50/50 mix of road and water transport, is only about 1.5 months.

The harvesting methods in use also have an effect. All solutions in wood procurement should fit into the entire chain and not cause unreasonable cost elsewhere. In most cases transport forms a service function and must meet the demands imposed upon it by the wood assortments required at the mill and the conditions prevalent at the forest end. Seldom is wood harvested in a form to minimize only transport costs.

Due to the many factors mentioned above, the transport method giving the lowest direct cost is not always the one chosen. However, direct cost forms one of the basic criteria in transport method choice. The direct cost of truck transport to the mill is straight-forward; we have costs of loading, transport to mill and mill receiving. When dealing with railway or water transport we have many additional cost components. In both methods we have the additional cost of transport from the forest to the terminal, as well as terminal operational and maintenance costs. In bundle floating we also have the additional costs of bundle bindings, bundling and raft formation.

In bundle floating 40 to 60 % of the total direct cost is due to initial transport to the terminal, while terminal operations account for 15 to 20 %. The actual bundle towing operation only accounts for 20 to 30 % of the total direct cost, while the corresponding value for mill receiving is 5 to 10 % (Uiton kehittämisryhmä 1980). From the above we can see that 70 to 80 % of the total direct bundle floating cost occurs over approximately 15 % of the total distance for the method.

Road transport is the most flexible of the three methods. This is because we are dealing with small truck-load units. In railway transport, discounts can be achieved by dispatching larger volumes of wood at a time (e.g. 1 000 m^3 per train load) and throughout the year. Time is also spent in transporting the wood to the railway terminal. Water transport has the largest delay time of the three methods. One reason is due to seasonal factors; the waterways freeze over during winter and floating is only possible for 5 to 6 months between May and November. The navigational period for water transport can be extended through the use of barges.

As mentioned earlier the additional cost due to interest on the wood investment has been given considerable attention. For small unintegrated operations road transport is solely relied on. For small firms only a small buffer inventory is required and they are flexible to market demands and wood supply. Since they have a low capital investment, as opposed to a pulp and paper mill, wood shortages do not pose a serious consequence, when compared to a pulp and paper mill. Also, the area from which wood is procured is quite small and thus suited to road transport. The cost of interest thus forms a much larger criteria for smaller firms.

When dealing with a large mill complex and thus large wood requirements, the importance of solely interest cost decreases. A buffer storage is required to ensure against wood shortages. Wood storages are also helpful to even out discontinuity between wood demanded and wood available on the market. Trying to juggle 340 000 forest owners to sell or not sell an additional 5 or 10 M(m^3) from one year to the next is near to impossible, as apparent from the recent difficulties experienced in wood sales from private forests. As mentioned earlier, the seasonal nature of cuttings also results in wood inventories. Another point to remember when dealing with large wood volumes is that, even though truck transport is the quickest method to get a load of wood to the mill, the movement of an entire inventory by the other methods can be competitive with truck transport. For example, the average raft size on Lake Saimaa is slightly larger than 20 000 m^3: i.e. over 500 truck loads. To ensure against wood shortages Eskelinen and Peltonen (1977) state that the optimal inventory for a Finnish firm is 40 to 45 % of the annual wood requirement: i.e. 4.8 to 5.4 month wood supply. Assuming uniform purchasing and harvesting operations throughout the year, the majority (about 90 %) could be stored as standing inventory. Since there is usually limited space at millyards, bundle floating allows an excellent opportunity to eleviate millyard congestion.

The choice of a long-distance transport method in south-eastern Finland also assumes that the method services the point of dispatch and the destination. Once wood is transferred from road transport to railway or water transport, it should be delivered by that method to the destination. This is due to the high interface costs when transferring from one method to another. For example, lifting bundled wood out of water and onto truck costs from 7 to in excess of 10 FIM/m^3, depending upon the conditions. This is equal to about a 30 to 40 km marginal increase in truck transport distance. Generally, road transport can be used in all cases except when extraction occurs in island or shoreline forests accessible only by water.

Certain poorly floating wood assortments, for example chips, fresh hardwood pulpwood, birch logs and small diameter fresh softwood pulpwood, limit the use of bundle floating if additional buoyancy or barges are not used. The extent of wood deterioration has a direct effect on the final product value and processing costs. Generally, if wood must be stored, it should be stored in water to minimize deterioriation due to fungi and insects. Wood stored on land (i.e. at roadside, railway terminal or millyard) would have to be continuously sprinkled with water or chemically treated. In bundle floating 10 to 15 % of the bundle is above the water´s surface and thus subject to wood damaging agents. Storage also has effects on barking, pulping processes, chemical requirements, pulp quality and yield, and yield of side products (e.g. pine oil and turpentine). Direct delivery of wood to the mill would give the best results, but if storage is required, water storage gives the best results (Vesikallio 1979).

By service we mean the period when a method can be used. As mentioned earlier, the use of water transport is limited to the navigational season. Dependability reflects the susceptiblity of a method to environmental and external factors.

National economic factors

When examining transport methods from a national economic point of view one must account for the investment required to establish, maintain and operate the different transport networks. Other factors which must be accounted for are: productivity of labour and capital, consumption of fuel and lubricants, effect on the environment, domestic share, dependability, etc.

Heikkerö (1979) makes a comparison between the balance of expenditure and income for the State by transport method. According to Heikkerö (1979), in 1977 70 % of the State´s expenditure on truck transport was recovered through taxes directly related to truck transport. To cover expenditures fully, truck transport tariffs would have had to been increased by 5 %. The corresponding values for railway transport and floating were 40 % and 20 to 40 %, respectively. Table 4 gives the net costs to the State by transport methods. It must be pointed out that the cost for floating is larger than it would be if the channels were only used for floating. This is because channels are built to a higher standard to accomodate inland vessel transport.

Table 4. Net costs to the State by transport methods after expenditures and revenues.

Method	Net cost to State, p/(m^3 · km)	National economic accident cost, p/(m^3 · km)
Truck transport	1.2	0.50
Railway transport	5.8	0.04
Inland vessel transport	1.0	--
Bundle floating	1.0	--

(Pertovaara 1982)

Uiton kehittämisryhmä (1980) and Pertovaara (1982) give the additional information listed below, comparing the transport methods from a national economic point of view:

- depending upon conditions, the man-day productivity in floating is 7 000 to 25 000 m^3· km and for truck transport it is about 5 000 m^3·km; a corresponding value for railway transport is not available
- the productivity for capital invested in floating equipment in 1980 was 265 m^3·km/1.00 FIM, while for truck transport it was 35 m^3·km/1.00 FIM and for railway transport (capital cost of railway cars only included) it was about 28 m^3·km/1.00 FIM
- the use of fuel in actual transport by truck is 10 times greater than for bundle floating per m^3·km, while for railway transport it is 3 times greater
- when taking into account energy required for actual transport, transport network construction and maintenance, and building the actual transport equipment, the energy requirements (oil equivalent, kg/(m^3·km)) for truck and railway transport, and floating are 0.042, 0.040 and 0.003, respectively
- a decrease in the trade balance of 20 million FIM/a would result if 5 M(m^3)/a were transferred from water transport to truck transport; inflated to today´s costs about 30 million FIM/a
- the domestic share of floating is 85 %, while for truck transport it is 30 %
- the environmental effect is only significant in free-floating; in bundle floating little water surface area is required and loss of bark and leeching of chemicals into the water is minimal due to bundling, however there is a local effect

at large dumping terminals and millyard storages
- transferring wood to roads, from either railway transport or bundle floating, would result in greater environmental effects and roadways would be further stressed near built-up areas, thus resulting in increased traffic risks and road wear
- land storage of unbarked wood in the summer can cause damage to surrounding stands, while water stored wood generally has little effect, unless large quantities are stored unbarked near coniferous forests over a long time since 10 to 15 % of the bundle volume is susceptible to insect damage unless the bundles are rotated or sprinkled with water
- the majority of waterway channels are usable for floating with little or no improvements required; also maintenance of waterways is minimal since they do not wear with use
- a waterway transport network is the most dependable method in times of crisis; e.g. energy supply problems

RATIONALIZATION WOOD TRANSPORT IN PRACTICE

As mentioned in the introduction, there are many firms with mills at different locations procuring wood in the area. In floating, the irrational operation of many different firms on the same channels became apparent quite early in industrial wood procurement as we know it today. Thus, the Kymi Floating Association was formed in 1873 (Seppänen 1937). In the Saimaa area, Pielis Elfs Flötnings Aktiebolag Oy was formed in 1886 by two companies floating on the Pielis River. Gradually, a number of floating associations and companies were formed in the area. In 1930 the Savo Floating Association and Northern Karelian Floating Association were formed, and are still in operation today. The two associations are responsible for floating in the northern half of the area and at two channel bottlenecks in the southern half (cooperative floating). Rationalization of private floating in the southern half of the area has also occurred and only two companies, Tehdaspuu Oy and Enso-Gutzeit Oy, have floating operations today. Floating associations are non-profit organizations who transport wood in an area and distribute costs to the member companies according to their share of the transport output. In the private floating area, contracts are made between companies with floating operations and other companies with wood to be transported.

Tehdaspuu Oy, which started operations in 1968, was another step in rationalization of wood procurement in the area. It is responsible for procuring wood for four separate companies. This cooperative venture allowed the elimination of overlapping organizations. Cross-hauling by the four companies could also be eliminated.

Tehdaspuu Oy and Enso-Gutzeit Oy, the two largest wood procurement organizations in the area, also employ optimization models for aiding long-distance transport decision-making. The decision areas are generally based on municipal areas and employ average costs from the areas to mills. Metsäteho, the Forest Work Study Section of the Central Association of Finnish Forest Industries, has also developed a number of mathematical methods for wood procurement optimization (Eskelinen 1984, Eskelinen and Peltonen 1982, 1980 and 1977). Although the methods give valuable information and are helpful in long-distance transport decision-making, they are subject to the limitations mentioned in the introduction. To make the methods operational, since they are based mainly on mathematical programming techniques, simplification of the problem and averages for areas must be used. Gillam (1969) states that mathematical programming is only applicable to hypothetical problems and is of little use in practice. Also, a clear picture of the overall transport situation is not easily available from the above methods.

Other rationalization has occurred, resulting through practical experience and research. There have been major developments in truck transport to keep it competitive. This is apparent from the section on long-distance transport information. Although railway transport and floating should be less susceptible to inflationary pressures than truck transport (Vesikallio and Salminen 1978), the rate of increase in truck transport from 1972 to 1982 was slightly less. In railway transport, special cars have been developed and unnecessary terminals discontinued. Improving the condition of terminals in use has also been another important development. In water transport, floating operations have been concentrated into the main channels, and terminal, towing and transfer facility operations developed. The use of redundant terminals have been discontinued and today, based on average minimum distance to terminals, the optimum terminal distribution has been reached. Only in some individual cases are terminal location improvements required. Any reduction in the number of terminals today would result in excessive increases in initial transport distance, while additional terminals would have no significant effect on reducing the average distance to terminals. Increasing the flexibility of water transport through the use of barges is also under investigation.

DATABASE FOR SIMULATION EXPERIMENTS

This section briefly introduces a database based on the uniform coordinate system. The uniform coordinate system is a grid system (perpendicular intersecting lines) based on the Gauss-Krüger map projection. In Finland, one projection corridor is used to cover the entire country. The centreline of longitude for the corridor is 27°E. This corresponds to the grid central meridian which is 500. Lines of latitude of 60°N and 64°N intersect the grid central meridian at grid lines 6710 and 7100. By using the uniform grid coordinate system, all grid squares have the same area since the effect of the earth's curvature is eliminated. Storage of data at uniform coordinates is simpler and its use in simulation models made possible.

A grid with a 2.5 km interval between grid lines was chosen in the study. The scale of the map mosaic covering the area was 1:200 000; the distance between map grid lines was 1.25 cm. Each grid square covers an area of 6.25 km^2 and it forms the basic unit of each information matrix having dimensions of 144 x 114 (l x w). Due to the shape of the watersheds under study, 9 048 of the total 16 416 squares lay in the study area. Figures 3, 5 and 6 were drawn from hard copies of information matrices. The Y and X axes of the computer printouts are not of the same scale due to the difference between character density per line and line density. Thus, figures 3, 5 and 6 show the area to be more elongated than it actually is.

When registering the transportation system information the map area covered by each grid square was examined. If it did not lay in the study area it was labled according to whether it was in another area of Finland or in the Soviet Union. Otherwise the presence of the following features was recorded:

1. roads
   11. highway network
      111. class I (primary national) highway
      112. class II highway
      113. unsurfaced highway
   12. community road
      121. bound surface
      122. unsurfaced
   13. private road
2. railway network
   21. actual railway
   22. railway terminal
      221. terminal with stationary crane
      222. terminal without stationary crane
   23. railway spur
3. water transport network
   31. water transport channel
      311. bundle floating channel in use
      312. bundle floating channel not it use
      313. free-floating channel
   32. bundle transfer facility
      321. bundle crane/track
      322. lock
   33. water transport terminal
      331. bundle dumping terminal in use
         3311. dumping ramp only
         3312. ice storage area only
         3313. dumping ramp and ice storage area
      332. bundle dumping terminal in sporadic use
      333. abandoned bundle dumping terminal
      334. harbour
4. watershed
5. water coverage percentage
6. mill
   61. sawmill
   62. wood-based panel mill
      621. plywood mill
      622. particleboard mill
      623. chipboard mill
   63. pulp and/or paper mill
7. district forestry board
8. municipality

Additional information relating to the area was also gathered: for example, annual allowable drain by wood assortments and district forestry boards, wood volumes dispatched from terminals, industrial cuttings, wood consumption at mills, channel costs, etc.

The storage of the above data for each grid square is only possible with a computer. With the data readily available in digital form, information matrices could be developed. Simulation models and experiments could be easily devised and used in a heuristic manner to help in long-distance transport evaluation and decision-making. A set of transport route search algorithms were devised for the system. A series of costing subroutines also allows the determination of actual transport costs. By entering the grid coordinates of the source and destination, and the wood assortment to be transported, transport between the two points by all transport methods is simulated and pertinent information produced. This is done with the aid of a master program combining the above mentioned information and subroutines.

Due to the nature of this paper, further explanation of the above heuristic simulation system is not possible. A major report dealing with the above will be published by the author in the near future.

SUMMARY

Since long-distance transport occurs in a dynamic environment with the presence of uncertainty, decision-making is very difficult. Rationalization of wood delivery has occurred in many areas; from the consolidation of wood procurement operations, to the actual development of each method. When deciding on the proper use of long-distance transport methods there are both business economic and national economic points of view. Generally the following business economic factors must be taken into account:

1) availability of wood for purchasing
2) harvesting schedule (i.e. availability of wood at roadside)
3) harvesting methods in use and costs
4) direct transport costs
5) time required for transport of wood from forest to mill
6) technical factors in regard to presence of suitable transport routes and effect on wood quality
7) wood holding costs at the mill
8) dependability and service provided by each method
9) wood demand at the mill

In regard to national economic factors, the competitiveness of each method depends mainly on the productivity of various resources: for example, labour, energy and capital. A transport method's effect on the environment is another factor. The ratio between domestic and imported materials required by each method is also important. The dependability and applicabiltiy of each method in uncertain conditions should also be accounted for.

Mathematical programming techniques have been used to a wide extent in aiding transport decision-making. However, use of the methods is limited due to the very large number of variables involved and uncertainty.

This paper has outlined the environment and factors which had to be accounted for in a study dealing with the development of a system to help in the coordination of the variations in water transport and wood procurement. The system, a heuristic simulation system, was briefly introduced. A detailed description of the system was not possible due to the nature of the paper. However, since all information relating to the transport system in the area is readily available, transportation problems can be readily simulated, and the information used in problem solving and decision-making. A system of this type is also applicable in solving other problems related to forestry or in fact, any other field with a geographical distribution.

LITERATURE CITED

Eskelinen, A. 1984. Kaukokuljetuksen vaihtoehtolaskentasysteemi. Metsätehon katsaus 3. 4 pp.

Eskelinen, A. and J. Peltonen. 1982. Puunkorjuun vaihtoehtolaskentasysteemi puunhankinnan suunnittelussa. Metsätehon katsaus 20. 4 pp.

———— " ———— 1980. Suunnittelusysteemi puunkorjeen menetelmävalintaan. Metsätehon katsaus 16. 4 pp.

———— " ———— 1977. Puunhankinnan suunnittelumalleilla suoritettava raakapuuvarastojen koon optimointi (Summary: Optimization of the size of roundwood storages performed by logging planning models). Metsätehon tiedotus 343. 29 pp.

Gillam, D. 1969. CIP puts computers to work in woodlands. Can. For. Ind. 89(4): 42 - 43.

Hakkarainen, A.E. 1978. Mitä on puunkorjuun rationalisointi? Metsätehon katsaus 11. 4 pp.

Heikkerö, T. 1979. Economics of water transport and its impact on other transport alternatives. Proceedings of IUFRO S3.01-04, Symposium on Water Transport of Wood, Univ. of Helsinki, Dept. of Logging and Utilization of Forest Products, Res. Notes 40: 133 - 162.

Huttunen, T. 1983. Suomen puunkäyttö, poistuma ja metsätase 1981-83 (Summary: Wood consumption, total drain and forest balance in Finland, 1981-83). Folia Forestalia 565. 79 pp.

Kuusela, K. and S. Salminen. 1983. Metsävarat Etelä-Suomen kuuden pohjoisimman piirimetsälautakunnan alueella 1979 - 1982 sekä koko Etelä-Suomessa 1977-82 (Summary: Forest resources in the six northernmost forestry board districts of South Finland, 1979 - 1982, and in the whole of South Finland, 1977-82). Folia Forestalia 568. 79 pp.

Pertovaara, H. 1982. Uitto- ja väylänrakennustekniikka. Lecture series booklet, Helsinki. 235 pp.

Salminen, J. 1983. Metsäkuljetusmenetelmien vertailu. Metsätehon katsaus 5. 4 pp.

Seppänen, O. 1937. Saimaan vesistön uittoväylät ja uittojen organisaatio niissä. Acta Forestalia Fennica 46. 168 pp.

TVH. 1979. Väylätilasto 1979. Tie- ja vesirakennushallitus, vesitieosasto, tutkimustoimisto, Helsinki. 33 pp.

TVL. 1983. Road and waterway construction. Official Statistics of Finland XIX:98. 71 pp.

Uiton kehittämisryhmä. 1980. Puutavaran uiton kehittäminen. Mimeograph, Helsinki. 43 pp.

Uusitalo, M. (ed.). 1983. Yearbook of forest statistics 1982. Official Statistics of Finland XVII A:14, Folia Forestalia 550. 218 pp.

Vesikallio, H. 1981. Metsäteollisuusyritysten puunhankinta muuttuvassa yhteiskunnassa (Summary: The timber procurement of forest industry companies in the changing society). Metsätehon tiedotus 371. 62 pp.

—— " —— 1979. Water transport from a wood quality point-of-view. Proceedings of IUFRO S3.01-04, Symposium on Water Transport of Wood, Univ. of Helsinki, Dept. of Logging and Utilization of Forest Products, Res. Notes 40: 123 - 130.

Vesikallio, H. and J. Salminen. 1978. Raakapuun uiton kilpailukyky. Suomen Itsenäisyyden Juhlavuoden 1967 Rahasto, Sarja B, 47. 69 pp.

Wiiala, A. 1962. Yksityiset tiet. Vammalan Kirjapaino Oy, Vammala. 243 pp.

CONTROL OF WOOD DELIVERY AND ASSOCIATED WOOD INVENTORY IMPLICATIONS IN NEW ZEALAND[1]

J.E. Galbraith[2] R.N. O'Reilly[3]

Abstract. - The experience of controlling wood deliveries and managing log inventories at the N.Z. Forest Products Limited, Kinleith mills is described. There are a number of geographical, organisational and climatic factors which allow close control of wood flow and minimal wood inventories at Kinleith. Operations research techniques were first applied to aid the management of the wood flow in 1965 and there have been a number of studies since to further refine control of the system.

Minimal inventories, equivalent to only a few days of usage, offer significant advantages in fresher wood, reduced handling costs and capital servicing. However, the resulting flow system is very dynamic and requires considerable short term control effort.

Key components of successful wood flow control were found to be :

- understanding the variability of the wood supply and demand and, where possible, improving forecasting.
- a system of short term (weekly) review and control.
- reasonably accurate estimates of inventories.

In the final analysis, control actions are a compromise between the need to return the system to target as soon as possible and the need to preserve some stability in wood production and delivery rates and hence maintain efficiency.

INTRODUCTION

The management of wood flows in a forest harvesting and utilisation operation has many similar characteristics to the management of any material supply, handling and processing system :

- there must be an overall balance of inputs to outputs.
- there are a number of processes within the operation, working at variable rates, and these too must be balanced.
- buffer stocks, or inventories, are held between the different processes to allow them to operate as independantly of upstream or downstream variation as possible. But the levels of the inventories must be economically examined and justified.

Many of the common business techniques of simulation, linear programming, inventory control, queuing theory, etc., can be applied to help improve the management of wood flows.

The experience in the use of some of these techniques, plus some basic control theory, in managing wood flows at the N.Z. Forest Products Limited Kinleith mills is described. Aspects of research to identify the factors that affect the efficiency of planning and control are also described and the implications for management discussed.

THE WOOD SUPPLY SYSTEM

The wood supply system at Kinleith has a number of characteristics which allow for, and demand, close control of wood flow and minimal wood inventories.

- Geographical location. The mills are located within the Kinleith forest, the main source of supply, and other sources of wood are relatively close. Average transport lead distance is a little over 30 km with a maximum of 120 km.
- Eighty to ninety per cent of the wood comes from Company owned or controlled sources.
- There is a close integration of growing, harvesting and utilisation functions.

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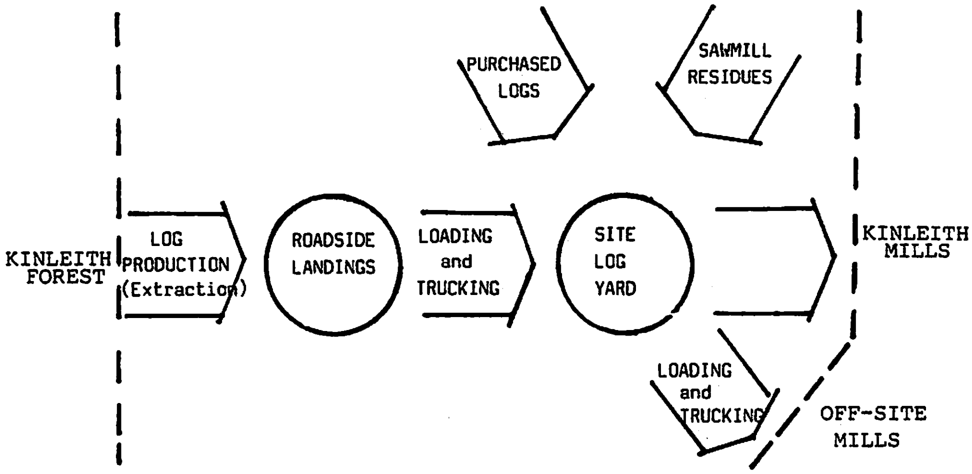


FIG. 1 - KINLEITH WOOD FLOW SYSTEM

- The climate is favourable for year round work.
- A single species, Pinus radiata, dominates the wood supply. Minor pine species and native hardwoods make up only 5% of the mix.
- The fast-grown radiata experiences quick deterioration after felling, by way of fungal and insect attack and drying out.

For the benefit of North American readers, the control of the wood supply organisation ("woodlands") extends through to the mill input, i.e. logs on the sawmill or chipper infeed chain or purchased chips on the outside chip storage slab. Thus the wood supply organisation manages the mill site log storage and handling, as well as delivery. Wood supply totals 2.5 million tonnes per annum.

INVENTORY CONTROL

Kinleith first took a scientific approach to setting target log inventory levels in 1965. By direct mathematical comparison of log supply and usage variation and by considering the costs of holding inventories, the following policy levels of site inventories were struck:

Pulpwood 3,800 tonnes
(equivalent to 1.3 days usage)
Sawlogs 1,900 tonnes
(equivalent to 0.5 days usage)

These were minimum safety levels; site log inventories were built up on top of these levels Monday to Friday each week to cover five-day supply, seven-day usage pattern, and also built up to cover long holiday and Christmas periods. Thus the safety levels applied to the log inventories which should be on site on the next 'normal' Monday morning.

Wood inventories were also held in the forest at roadside landings and on the mill chip piles.

These first studies reported that the costs of handling inventory and of running out of wood, had only a small influence on the optimum minimum inventory level.

In 1974, following a doubling in pulpmill capacity and massive increases in finance interest rates (and therefore the cost of holding inventories) the log inventory policies were re-examined. This time a simulation approach was used. Historical distributions of log supply and usage, the costs of holding inventory, the costs of running out of wood and the costs of taking extraordinary measures to maintain supply, were combined in a stochastic simulation model. As a result, the recommended optimum safety levels for site log inventories (pulpwood and sawlogs combined) were:

7,000 tonnes
(equivalent to one day's usage in total).

And the chance of running out of wood was estimated as being once every four years. Despite the major changes in the magnitude of some of the inputs to the calculations, there was remarkably little change to the total inventory policy levels as a proportion of usage. The sensitivity of the optimum inventory level to changes in the various inputs was tested. It was found that the optimum levels were primarily a function of the patterns of variation in supply and usage, and were not at all sensitive to the cost of capital, the cost of running out, or the cost of handling excessive inventories.

A similar simulation approach to setting optimum inventory levels was subsequently applied to an Eastern Canadian pulpmill and similar principles emerged, i.e. that optimum inventory levels are primarily a function of the variations in supply and usage (Galbraith, 1977, Galbraith and Meng, 1981).

These findings are not too difficult to rationalise. For a reasonably balanced wood flow system, there will be a level of buffer inventories which will reduce the chance of running out of wood, and of overstocking, to an acceptably low level. At this level, the costs of such consequences are reduced by the same low level of probability.

Returning to the Kinleith experience; policies for log inventories were then set as:

Site:	
Pulpwood	4,000 tonnes (1.4 days usage)
Sawlogs -	
summer	1,875 tonnes (0.5 days usage)
winter	2,500 tonnes (0.7 days usage)
Forest:	
Pulpwood	15,000 tonnes (2.6 days usage)
Sawlogs -	
summer	5,000 tonnes (1.4 days usage)
winter	7,000 tonnes (2.0 days usage)

The forest log inventories were not set by scientific means, but rather by experience. At levels below those set, it was found that loaders spent an excessive amount of time shifting, and truck utilisation dropped off. Any loss in efficiency in loading and trucking would quickly negate the relatively small gains in reducing capital invested in inventory at this lower cost stage.

In addition, buffer stocks of chips were held on site on outside chip storage slabs.

PRODUCTION CONTROL

Classic inventory theory speaks of 'inventory control', i.e. the direct management and manipulation of inventories. In the wood supply system however, inventory control is a misnomer. Since wood inventories can generally not be manipulated by selling off excess or buying in to make up, it follows that the only effective action is to deal with the cause, not the symptom.

Fluctuations in inventories are a result of imbalances in supply and demand. Since the wood supply manager can generally not influence demand, if he is going to try to adhere to inventory policies he must have an effective method of production control.

A formal system of log production control was introduced at Kinleith in 1976. The basic planning horizon was set at one week. Log inventories in the forest were estimated at the end of each week and inventories on site were estimated daily.

The simple arithmetic basis for determining target log production for the week was:

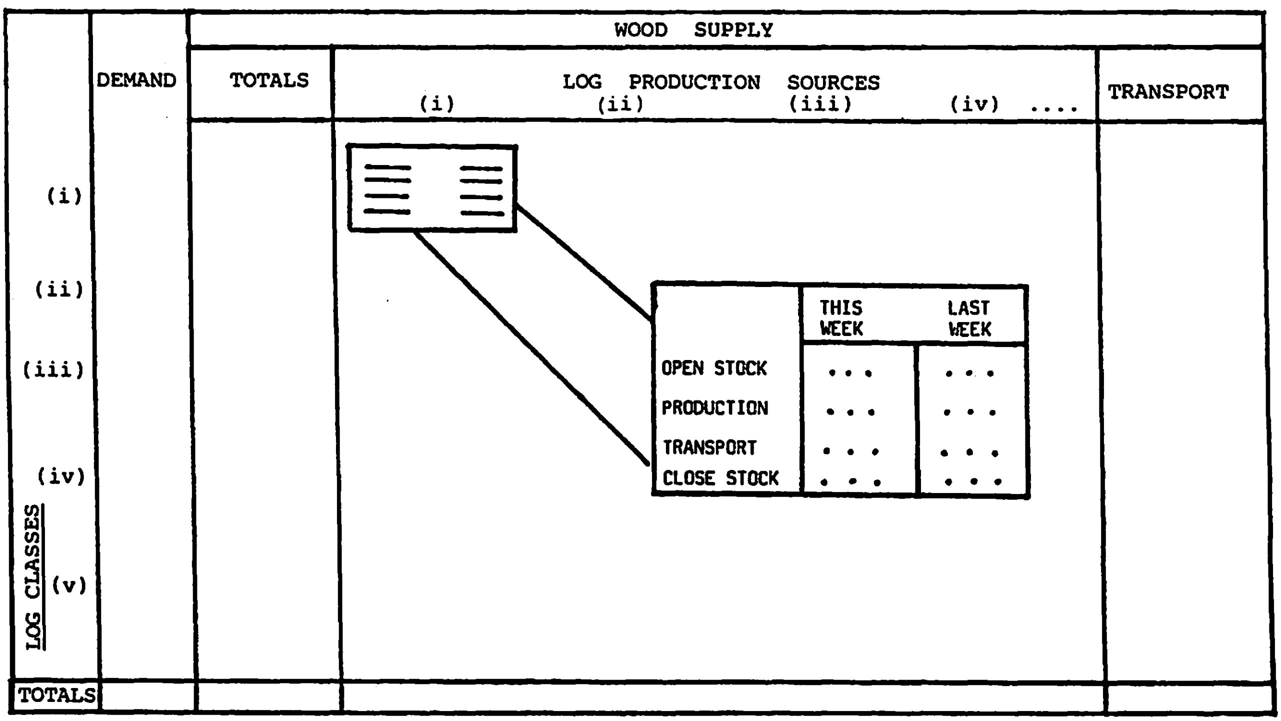


FIG. 2 - PRODUCTION CONTROL MATRIX (for weekly planning and control)

Forecast demand, plus target (policy) site and forest inventory, less actual beginning inventory.

and for determining target log transport (delivery) was:

Forecast demand, plus target site inventory, less actual site inventory.

These targets were then entered on a production control matrix board (fig.2). The matrix was broken down into the different log classes and log sources and discussed among the wood supply management people at the beginning of each week. At the same time, using measured delivery information and inventory change estimates, the actual productions and deliveries for the previous week could be compared to the plans for the previous week.

The advantage of the system was that it very closely linked forecast demand and planned supply, and kept log inventory targets as objectives each week. It also gave quick assessment of the effectiveness of control. The feedback loop linking supply and demand was very short and reactive.

Experience showed that the system was just too dynamic to be controlled this closely. Fluctuations in demand in particular sometimes caused actual inventories to move significantly away from target within a week. Target inventories (particularly on site) were quite low compared with weekly demand, and it didn't take much of an imbalance in flow to cause a major inventory movement.

When this happened, it became unrealistic to expect the system to be returned to target in the next week.

At each processing stage of a wood flow system, the general objective of its management is to achieve stability and security. Apart from the fact that people generally like to be stable and secure, it also helps to improve efficiency. A logging crew, for example, cannot be expected to operate efficiently if it is constantly being required to move its output up and down, and jump from area to area. As noted before, losses in efficiency can quickly negate gains in e.g. inventory costs.

Yet if wood flows are to be kept in reasonable balance, and if the obvious benefits of optimum inventory levels are to be achieved, some degree of production control must be exercised.

The compromise was to move away from the objective of returning to target inventory levels necessarily in one week and to take a longer time horizon, appropriate to the size of the adjustment required.

This introduced another level to the planning process; a set of programmed productions and transports which were an agreed plan of action, often different to the target. The program figures represented the compromise of moving the system back toward target, but at a pace acceptable to the production management.

In summary, the three levels of weekly production planning and control data were then :

Target - a strict arithmetical calculation of demand, plus or minus an inventory adjustment to return inventories to target.

Program - an agreed plan of action, often different to target, but normally reflecting a move toward target.

Actual - the actual productions and deliveries at the end of the week, which could be compared to program to test the ability of area management to adhere to agreed plans.

EFFECTIVENESS OF CONTROL

In 1978 author O'Reilly began studying the wood flow system at Kinleith to identify its particular relationships. As an outside view it gave an interesting assessment of the effectiveness of the production control.

While numerous texts describe the techniques used in modelling (e.g. Daellenbach and George, 1977), there are few examples of the application of such techniques to the modelling of wood flow. Lönner (1968) and Newnham (1975) both applied linear programming to a wood supply problem to minimise the total cost of wood supply; however, both assumed a fixed mill demand situation. Hewson (1960) studied the dynamics of inventory using simulation in a variable demand situation, although his model allowed only restricted variation in both supply and demand. The above studies also suffer from a fault common to most forest operation models, which is to emphasise planning, with little thought to control: "To a considerable extent, control of operations has been left to operating personnel. The result is that planning and control have largely been done in isolation from one another, with little feedback from control personnel to planning personnel and even less attention by planners to the special problems of operational control" (Dykstra, 1981). The important characteristic of this operation is that the planning and control are purposefully linked, and thus in the research into the system, this connection is of prime importance.

The wood flow system at Kinleith was modelled to represent the planning and control activities under normal conditions (i.e. no major strikes or mill shutdowns). In the models, the relationships between the various stages in planning and control (i.e. demand → target → program → actual, for both wood production and wood transport) were derived; measures of variability were included in the models to reflect the real-world variation experienced.

Historical data was used to validate the model and then to study the significant relationships within the system.

Some important results of the study were :

The major inputs to the planning and control system are :

- The estimated log inventories in the forest and on site at the beginning of the week.
- Forecast demand for the different wood classes, expressed on a weekly basis.

(i) Estimates of inventories :

The accuracy of the estimates of log inventories are important on three counts :

- log inventories are a component of the formula for calculating required log production and deliveries for the week ahead.
- log deliveries are measured by weight coming on to the Kinleith site. Mills on site are fed directly from trucks or from stockpile. Therefore the actual input to a mill is assessed from the daily haul plus a stock adjustment.
- log inventories are also a component of the formula to calculate actual production and delivery.

Estimates of log inventories on forest roadside landings were known to be coarse and prone to error, depending on the experience and skills of the 20 or so different people making the estimates.

Log inventories on site were also estimated by eye but generally by the same one person and were independantly surveyed each month by volume measurement of the log piles.

Although there was more confidence in the estimates of the more critical site log inventories, there was a general requirement to improve estimating, as errors could not only result in incorrect planning, but also compound the problems of control.

(ii) Estimates of demand :

Each week the wood-using mills provided estimates of log demand for the coming week. For most of the mills the model showed that there was reasonably good correlation between actual usage and forecast demand. However, for one mill, unfortunately the largest user, forecasting was very poor and the model in fact showed little correlation between what it actually used and what it said it would need. Forecast demand was often set at or near mill capacity and so variation was normally in one direction - down. Being such a big user, the result was that log inventories in that class would often move very rapidly up, certainly at a faster rate and to a level beyond which the weekly control system could cope. The downward fluctuations were due to internal mill factors which are not within the control of the wood supply personnel.

Wood supply was then faced with an extended period of production control to try to bring the system back to target, often taking many weeks. The study added weight to the long term complaint of the wood supply people - the need for more reliable forecasting of demand.

In recent years forecasting improved as mill production became stable and as more realistic mill production targets were set.

Another interesting use of the modelling was to assess the effectiveness of wood flow control. As an example, the general finding was that there was reasonable correlation (though lower than expected) between actual and programmed log production. However, the performance of the transport phase was more significantly influenced by the forest log inventories, i.e. the wood <u>available</u> to haul, than the program, i.e. what was <u>required</u> to haul.

The transport phase, despite planning targets, was tending to work to move forest inventories, particularly if they were above target, and this in turn encouraged log production. This latter was a natural tendency of the production crews - somebody obviously wanted their wood!

The result was that the site inventories would build up and not until the log yard filled would transport slow and in turn slow production. The system was being driven by the supply end, not the demand end. Reaction to variation in demand and to inventory fluctuations was too slow as a consequence.

The solution was to put a lot more attention into requiring transport to hold to plan. If transport was reacting more quickly to demand this in turn would demonstrate, quickly and practically, the demand pattern to the producers. This helped reinforce, in a practical way, the message coming out of the weekly production control planning meetings. This was successful and, apart from taking a lot of inertia out of the control system, tended to push more inventory fluctuation out to the lower

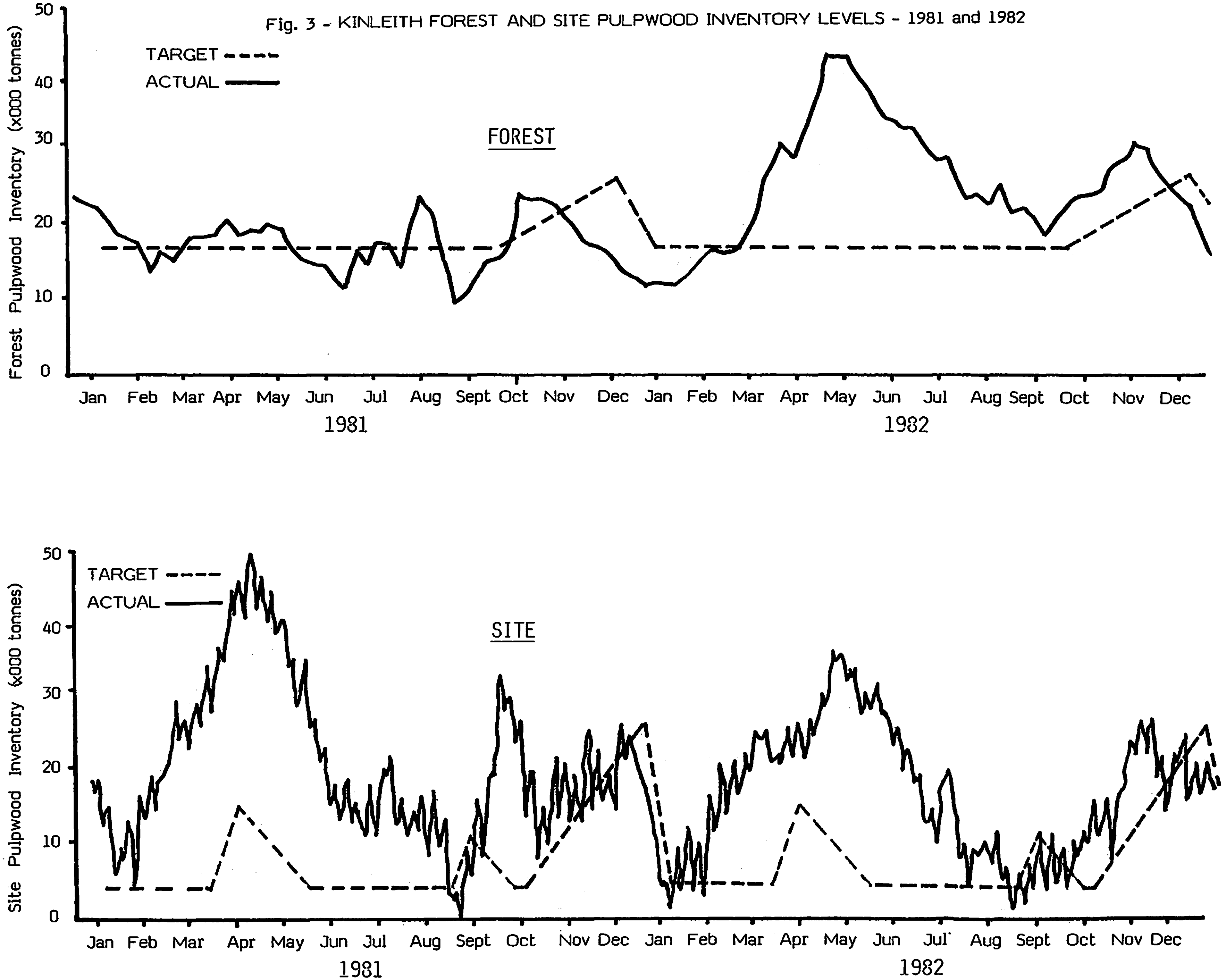


Fig. 3 - KINLEITH FOREST AND SITE PULPWOOD INVENTORY LEVELS - 1981 and 1982

cost forest end.

Figures 3 and 4 show the actual pulpwood log inventory levels in the forest and on the site for the years 1981 to 1983. Some observations :

(i) Three planned inventory buildups occur each year :

- in December to cover the reduced deliveries during the holiday period
- in April and either September or October as a result of planned maintenance shutdowns on pulpmill equipment.

These planned buildups are superimposed on the target inventory levels and the objective is to get inventories back to target as soon as practicable after the event.

(ii) The shape of the inventory profiles shows the tendency for the inventories to build up rapidly, generally due to a shortfall in usage, and then taking a considerably longer period of production control to bring the inventories back to target.

(iii) Comparing years 1981 and 1982 illustrates the effect of using transport more effectively in the control procedure. In 1981 a series of mill production problems in February and March, followed by an extended maintenance shutdown in April, caused a significant drop in usage. Because the transport phase did not react quickly enough to the reduced demand, site inventories continued to build up to the point where the mill yard was full. Through all this the forest log inventories did not move much at all. Thus the problem was carried at the highest cost stage, and incurred significant costs of handling excess stockpiles on site.

In 1982, when a similar pattern of reduced demand occurred, transport was controlled more effectively to match demand on site and most of the buildup in inventory was taken at the forest end.

As a final word on the effectiveness of the overall wood control system; the mills have never (barring major industrial action) run out of wood, and the system has operated with a site log yard which will hold at most only five days usage.

SUMMARY

Over the past 19 years at Kinleith, a process of scientific investigation, evolution and experience has produced a production control system which has successfully maintained wood supply with minimal log inventory holding facilities. The basis of control is a weekly planning and control procedure involving management directly concerned with wood supply. A series of optimum log inventory levels have been calculated which minimise the expected total cost of holding inventories (including the costs of running out of wood) and these optimum levels are used as planning targets. The procedure moves through the stages of :

TARGET = Forecast demand
+ target inventory
- actual inventory

PROGRAM = Agreed plan of action, moving toward target

ACTUAL = Actual performance at week end which can be compared with program.

Key inputs to the procedure are forecast demand and inventory estimates and it is important that these are as accurate as possible.

Close control of the transport (delivery) phase proved to be the most effective way of controlling the higher cost site inventory levels and influencing log production.

With the above procedures it has been possible to maintain a log supply of 2.5 million tonnes p.a. of a variety of different log classes, with a safety site inventory of only one day's log supply and a maximum site log yard capacity of only five days supply.

REFERENCES

DAELLENBACH, H.G., and GEORGE, J.A. (1977) Introduction to operations research techniques. Allyn and Bacon. 603 pgs.

DYKSTRA, D.P. (1981) Planning and control of operations in mountain forest. Proc. Div. III 17th World Congress, IUFRO, Japan. pp 189-201.

GALBRAITH, J.E. (1977) An economic analysis of pulpwood inventory requirements. Unpubl. thesis, M.Sc.F. degree, University of New Brunswick, Fredericton, N.B., Canada.

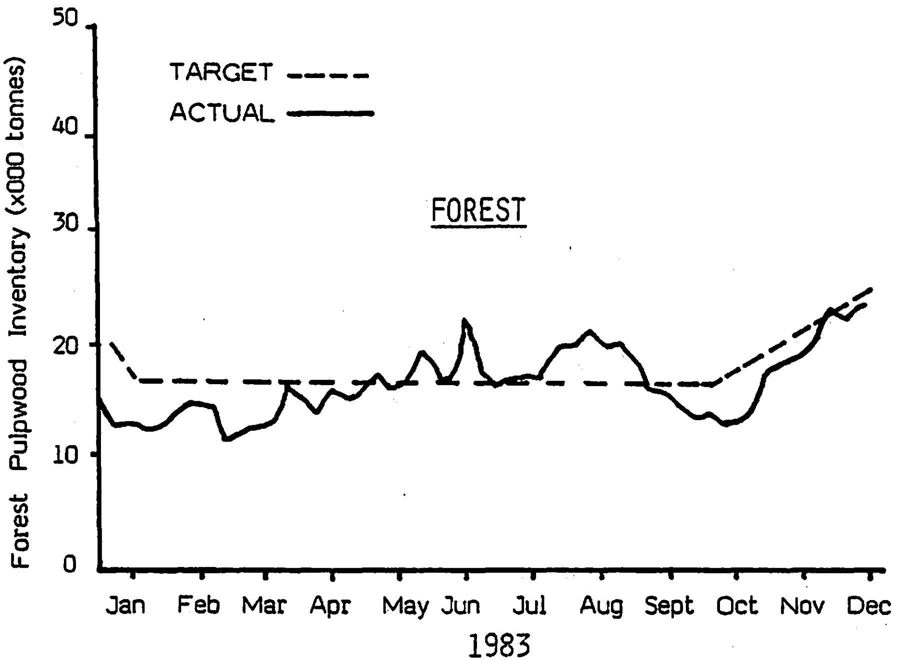
GALBRAITH, J.E., and MENG, C.H. (1981) Simulating optimum inventory of harvested wood. American Journal of Forestry, Vol.79, No.5, pp 292-295.

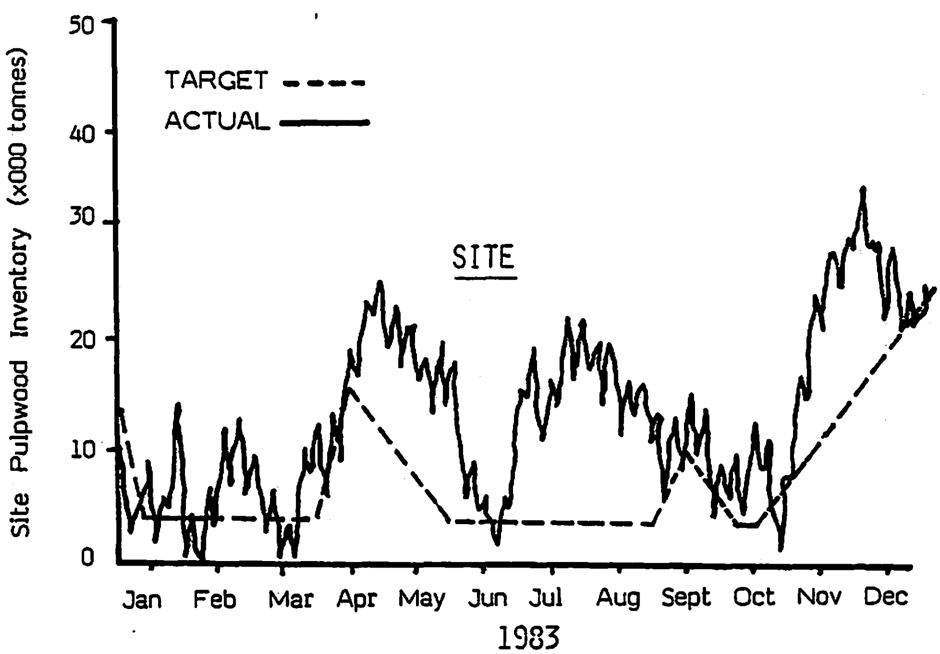
HEWSON, T.A. (1960) Simulation of pulpwood inventory dynamics in the operation of an integrated pulp and paper mill. TAPPI, 43(6):518-527.

LONNER, G. (1968) A system for short-term planning of logging, storing, and transportation of wood. Forskningstiftelsen Skogsarbeten, Bulletin 16, 104 pgs.

NEWNHAM, R.M. (1975) LOGPLAN - model for planning logging operations. Forest Management Institute, Information Report FMR-X-77. Ottawa. 59 pgs.

Fig. 4 - KINLEITH FOREST AND SITE PULPWOOD INVENTORY LEVELS - 1983





EFFECTIVE FOREST ROAD PLANNING FOR FOREST OPERATIONS AND THE ENVIRONMENT[1]

Yasushi Minamikata[2]

It is now the most important to minimize the influence of forest road construction on the forest environment. In this paper, methods to estimate the total length of forest roads in a planning area, to locate the roads as a networks, and to select the optimum route of the main forest roads etc. are presented.

INTRODUCTION

About sixty seven percent of the land area of Japan is covered with forest from the sub-tropical zone in the south or at low altitudes to the sub-frigid zone in the north or at high altitudes. The average temperature in the summer season is fifteen degrees and the average annual rainfall is 2,000 millimeters. Such a warm and rainy climate favors the growth of trees and the appearance of artificial forests might be traced back to about 400 years ago. Thirty nine percent of the forest area is now made up of artificial forests and the dominant species are japanese cedar, cypress,and larch. The Forest Agency in the long-range plan intends to enlarge this to fifty two percent by 2,025 A.D..

It takes more than two centuries for forest to recover from the damage caused by harvesting and revert to useful softwood forest again. In contrast the regeneration periods if artificial methods are used in less than seventy five years. However, in comparison with natural regeneration, artificial regeneration requires a lot of labour for planting, weeding, pruning and thinning. Usually, 200 to 400 men per hectare are said to be required through the entire regeneration periods, though this varies with tree species, regional customs, etc..

Generally speaking, the greater the labour required in stand establishment and the higher the labour cost, the more significant will be the road network in the forest. The Forest Agency therefore, in the long-range plan, calls for the opening up 440,000 kilometers of roads in the forest area, equivalent to eighteen meters per hectare when public roads passing through the forest area are included. But so far this has not been achieved and the present densities are very low compared to the target. In such circumstance, the demand for the expansion of the forest road system becomes greater.

On the other hand, there is a tendency to emphasize the influence of forest road construction on the ecosystem or natural environment of the forest. Opening up forest roads occasionally causes land slides sometimes on a large scale, so that it is very important to assess not only the economic effects of road construction on forestry but also the various impacts acting on the environment of the forest before building a dense road network.

DETERMINATION OF THE TOTAL LENGTH OF FOREST ROADS

There are three kinds of forest road in Japan, first, second and third class. The former two classes are forest roads for ordinary logging truck use. First class roads are trunk roads within the forest road network. Second class roads are the most popular and the total length constructed annually is far greater than that of first class roads. Third class roads are roads for the use of light types of vehicle with engine capacities less than 500 cubic centimeters. The main standards of the geometrical design are shown in table 1.

Table 1.--Standards of main geometric design of forest roads in Japan.

Road class	Design speed	Width	Shoulder	Radius	Grade
	(km/hr)	---------(m)-------------			-(%)--
1st	40(30)	4.0	0.5	60(40)	7(10)
2nd	30(20)	3.0	0.5(0.25)	30(20)	8(12)
3rd	20	2.0	0.5(0.25)	15(12)	9(14)

The figures in parenthesises are allowable values under the special conditions respectively.

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[1]Paper presented at the conference COFE/IUFRO - 1984. Fredericton, N.B., Canada, 15-18, August.

[2]Yasushi Minamikata is associate professor of Faculty of Agriculture, University of Tokyo, Tokyo, Japan.

Forest owners, including The National Forest Service, wish to increase the total length of road in their forest area as quickly as possible, so the length of third class roads opened annually is equivalent to or greater than the total length of first class and second class roads. The reasons are that low class roads are not expensive to construct and, if necessary, they can be upgraded in the future.

Under such circumstances, it is considered that it is time to introduce a new idea into the road network system, i.e. the compound road system which is composed of more than two kinds of forest road, not only high class roads but also low class roads (Minamikata 1977,1983). In this system, two kinds of forest road densities should be calculated first. One is the density of high class roads(d_c) at which the production costs of the two logging systems shown in figure 1 are equivalent to each other. The road system should be changed from the high class to the low class one once this density is reached. The other is the target density (d_l). The formulae to calculate forest road densities are as follows and include various factors such as the average volume to be harvested in cubic meters per hectare (V), labour costs in yen per hour (C_W), labour consumption in men per hectare during the plantation period (N_W), and non-productive wage owing to the lack of forest roads, e.g. to account for the walking time from the road side to logging site.

$$d_l = 50(\alpha_l \cdot V \cdot (1+\eta) \cdot (1+\eta'_l)/r_l + k \cdot (1+\eta) \cdot C_W \cdot N_W/500 \cdot S \cdot r_l)^{\frac{1}{2}} - d_0$$

$$d_c = (p^2/4 - q)^{\frac{1}{2}} - p/2$$

where $p = d_0 + (\beta_H - \beta_l)/(r_H - r_l) \cdot V$

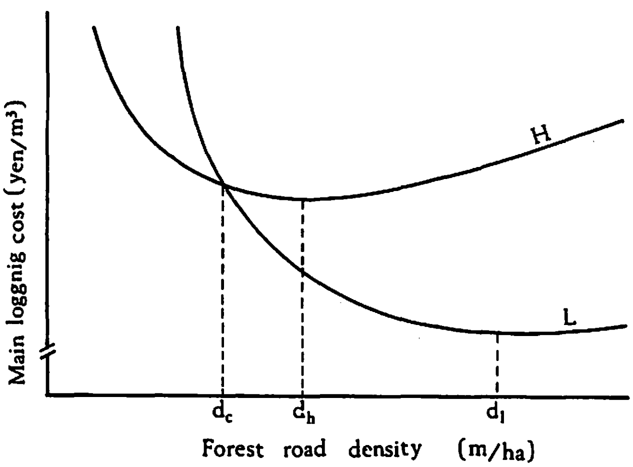

Figure 1--Concept of compound road network system. H : logging system with high standard roads and long span cable yarding. L : logging system with low standard roads and short span cable yarding.

$$q = (p - d_0) \cdot d_0 + (2500\, V \cdot (1+\eta) \cdot (\alpha_H \cdot (1+\eta'_H) - \alpha_l \cdot (1+\eta'_l)))/(r_H - r_l)$$

r : unit cost of road construction (yen/m), S : walking speed of labours (km/hr), k : the coefficient of the increment of the walking distance, and α ,β : coefficient related to the prehauling cost, d : density of public roads in the forest area.

The length of each class of road to be planned should be calculated from the densities of forest roads. From the point of view of the expansion of the forest road network, high class roads should be constructed until the point (d_c) attained. After that, the construction of low class roads should be continued until the target density (d_l) is reached.

COMPUTER LOCATION OF ROAD NETWORK IN OUTLINE

The overall planning of the forest road network consists of two main processes. One is the determination of the forest road length to be constructed, and the other is the location of the optimum route of the network. The former can be obtained by calculating the densities of each road class. As for the latter, there have until recently been no theoretical methods. Therefore, route location is left to the individual engineer in charge of the planning of forest roads. This ought to be a person of experience as it is desirable that route location is entrusted to an expert. But it seems to be almost impossible to maximise the effect of forest roads throughout the planning area.

A theoretical method to locate forest roads has been developed recently (Kobayashi 1983) and has proved to be applicable to network planning in mountainous regions. The operational flow chart of the planning system for route location using a computer is shown in figure 2. "A" in the figure represents the preparation of the data and is divided into three parts. The first is the process to produce a digital terrain model of the planning area and to define values such as the construction cost of roads, the cost of prehauling and the cost of the unproductive labour. The second is the process to prepare data concerning the condition of the existing road system in the planning area. The third is the process to obtain the data such as the timber volume to be harvested and the amount of labour per hectare needed for stand establishment. "B" is the process to calculate the road length required and to estimate the investment effect of road sections. "C" outputs the results.

The planning system for route location is based on the mesh analysis method. Using this method, the forest road is extended section by section. Extensions consisting of roads along the sides of the grid or along the diagonal except the direction along which the route has already been laid are considered and road section which has the highest economic effect will be selected as the next route section to be extended. The procedure is then

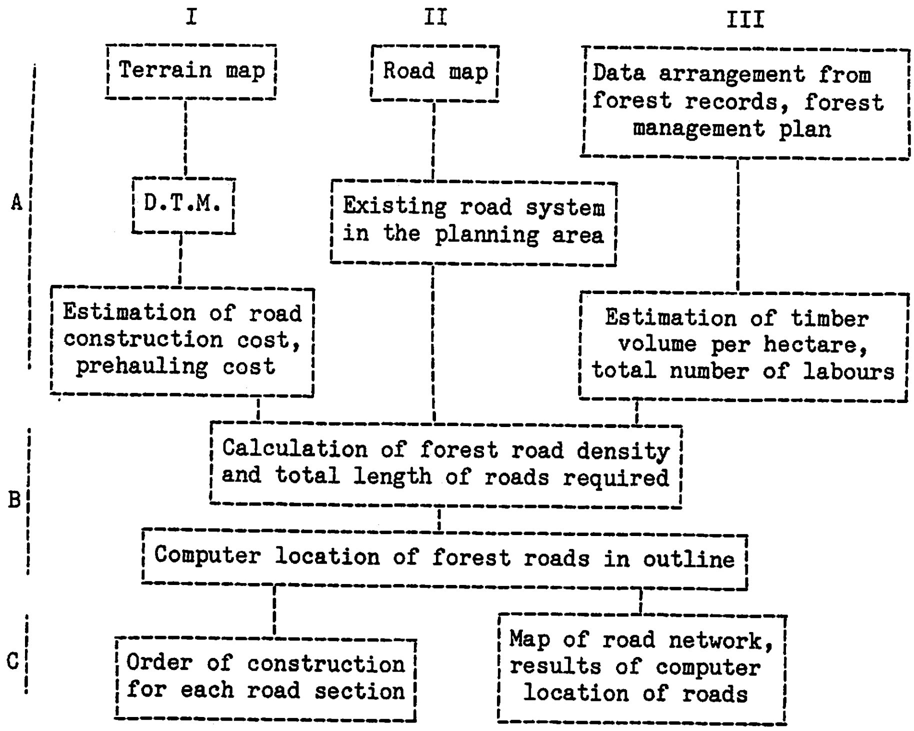

Figure 2.--Operational flow chart for planning system for road-route location with an electronic computer

repeated from the new starting point. The route location, using a computer as mentioned above, will be continued until the length of the forest road is equal to the target length in the planning area. As a result, this method can provide the planner of the forest road network with an optimum location for the road route.

The results of this method may not be accurate enough due to the limits imposed by using mesh analysis. But the planner, using the results shown in figure 3, will be able to make a plan confidently or objectively on a terrain map of the planning area to the scale of 1/50000 or 1/25000. This is the great merit of a computer aid for route location.

ROUTE PROJECTION FOR TRUNK ROADS

Long forest trunk roads often pass through two or three water-sheds. As a matter of course, there is a high probability that they will pass through high altitude and cross steep mountain slopes and have a serious impact not only on the forest environment but also on the scenery.

Until about ten years ago, forest road engineers did not pay enough attention to the environmental damage caused by opening up forest roads or to construction techniques designed to minimize disasters. A lot of damage occurred to the forest environment. This led to or stimulated the move-

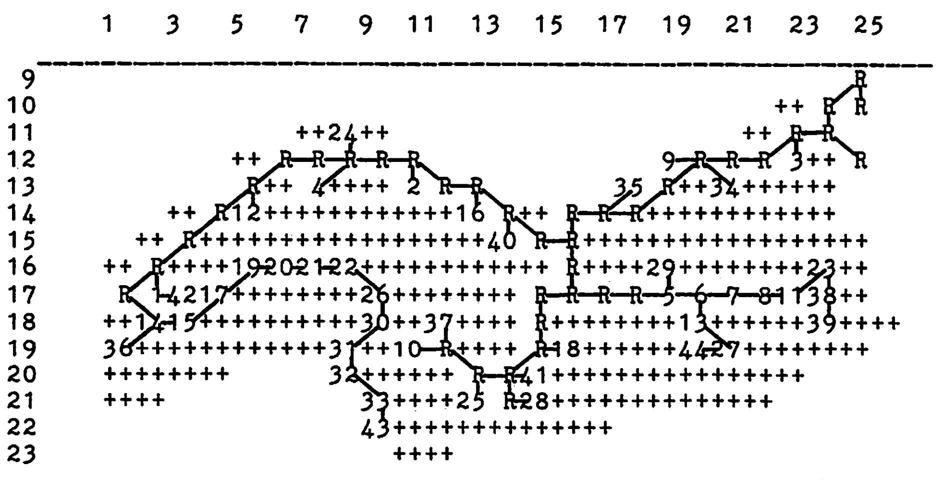

Figure 3.--Results of computer location of road network. R:existing roads, Figures:order of construction.

ment for nature protection, and made us realize the necessity of establishing new methods to find the best route which might cause minimum damage to the forest environment.

Nowadays, route location for long trunk forest roads is carried out using the mesh analysis method as follows (Minamikata 1983).

The planning area, which might be the service area for the road, is covered with rectangular grids 500m by 500m and each grid is numbered. After this process, the following items are estimated and scored for every grid.

Estimation category A : factors related to the conservation of forest land, such as the land slope, calculated from the altitude of the grid corners, classified into five grades (less than 15°, 15° - 25°, 25° - 35°, 35° - 45°, more than 45°), the area ratio of landslides to the grid area, classified into three grades (less than 2 %, 2 - 10 %, more than 10 %), existence of fault lines or a fracture zone, classified into three grades (none in or around the grids, none in the grid but around, in the grids) and the existence of creeping land classified into the same grades the previous factor.

Estimation category B : factors related to nature conservation such as the designation of protection forests, National or Prefectural Parks, and existence of significant species of floura or fauna. Scoring of these factors is adjusted according to the type of forest in the grid. For example, in a grid containing National Park forest the scores for the category would be increased, etc..

Estimation category C : factors related to forestry such as the volume of timber per unit area, artificial forest or not, and stand age.

The next step in the route projection is the calculation of a total score for each road section from the mesh i to j which are connectable.

Defining $(E_e)_{ij}$ and $(E_f)_{ij}$ as the sum of scores included in category A and B, and category C for grid i and j respectively, the total score for the same road section from grid i to j, $(E_t)_{ij}$, is given by the following equation.

$$(E_t)_{ij} = ((E_e)_{ij} \cdot k_e + (E_f)_{ij} \cdot k_f) \cdot (D_{ij} \cdot (1+S_{ij} - M)/M)^{k_r}$$

where k_e: the weight for categorys A and B (environmental factors), k_f: the weight for the category C (forestry factors), k_r: the weight for the construction cost of roads, D_{ij} : distance from mesh i to j (rectangular direction : 500m, diagonal direction : $500\sqrt{2}$m), S_{ij}: the average gradient between mesh i and j in percent, and if S_{ij} is less than M, then $(S_{ij} - M)/M$ is taken as zero.

The optimum route for the forest road is shown as a series of grids by using the shortest path algorithm from the theory of graphs (Iri 1976). Up to five terminal points of the road may be preappointed. As a result, routes equal in numbers to the combination of the start points and end points will be generated. It is also possible to appoint some points through which the road has to pass. The final route will be chosen from these alternative routes, which will have the minimum total score for $(E_t)_{ij}$.

Figure 4 shows the series of grids as an outlined location of the forest road. The dotted line shows the result in the case that intermediate points are preappointed. The topographic map overlapped with the series of the grids as an outlined location of the forest road will be very helpful for the road engineer to make a route projection within or along the series of grids or in adjacent grids on the contour map. This method is useful and sufficiently accurate for route location on the map.

If the final route passes through grids with high scores, attention must be payed to the design and construction of the road sections and it must be made clear what kinds of countermeasures should be adopted. Furtheremore, some countermeasures to maintain scenic beauty should also be indicated for those places which can be seen from several view points within a four or five kilometer zone on both sides of the final route.

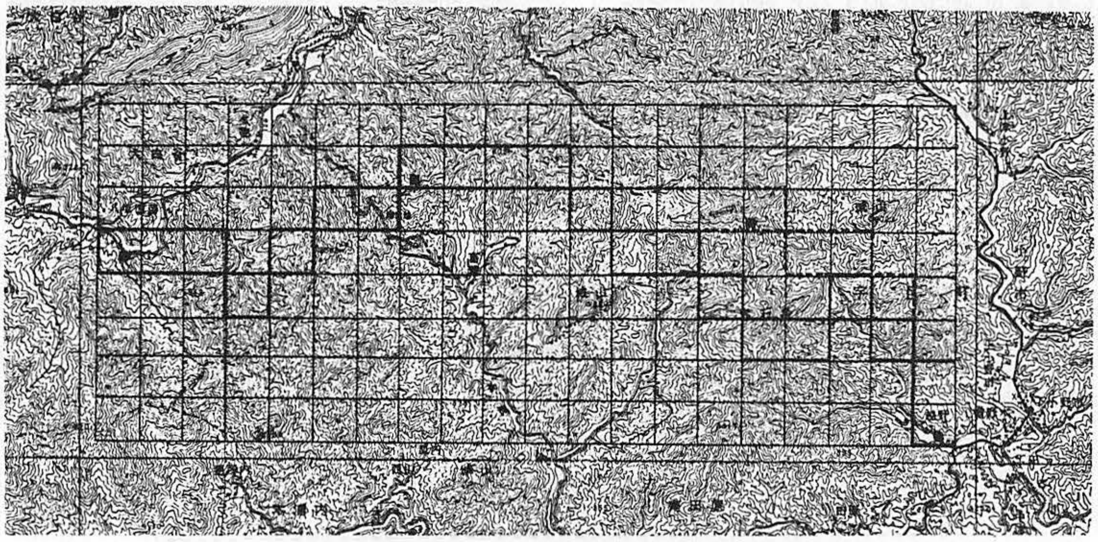

Figure 4.--Contour map overlaped with the series of grids showing the best route for the forest road.

SOME CONSTRUCTION TECHNIQUES FOR PREVENTING THE FOREST LAND FROM DAMAGE

The main machine for the earth work

The construction of high standard forest roads is often accompanied by a large amount cut and fill works, especially in steep terrains. It usually results in a lot of waste material being produced along the route. Until recently an angle-dozer had been the major machine for earth work of this type and it could only push the residual soil or rock outside the right of way to the down slope, the vegetation on the mountain side below the formation line of the road was injured or killed by the dumped material. This aroused a lot of emotion.

About six or seven years ago, the angle-dozer was replaced with the back-hoe, which is nowadays the most important machine for earth work and it can treat waste material efficiently without the accompanying serious damage to the forest environment. Cutting works on steep mountain sides are carried out with this machine and the waste materials are removed by dump truck to a special disposal area on a gentle slope (figure 5). The angle-dozer is only used as a supplemental machine for earth work at present.

The road side and occasionally the foot of the disposal area are strengthened by concrete or concrete block wall.

Slope seeding

Grass seeding has become a very common treatment for slope stabilization during the final stage of forest road construction. Usually, grass seeds are sprayed by compressor on the slope together with a base material which consists of wood fibers, adhesive and fertilizing materials, or the slope is covered with many sheet of wood fiber mat holding grass seeds and the fertilizer (figure 6).

The surface erosion control is indispensable from the view point of land protection in order not only to prevent the slope from erosion, such as the formation of small gullies, but also to improve the appearance of the road side.

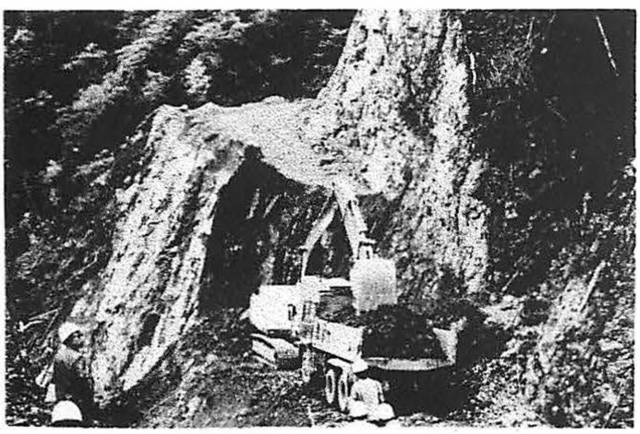

Figure 5.--Earth work with the back-hoe and dump trucks.

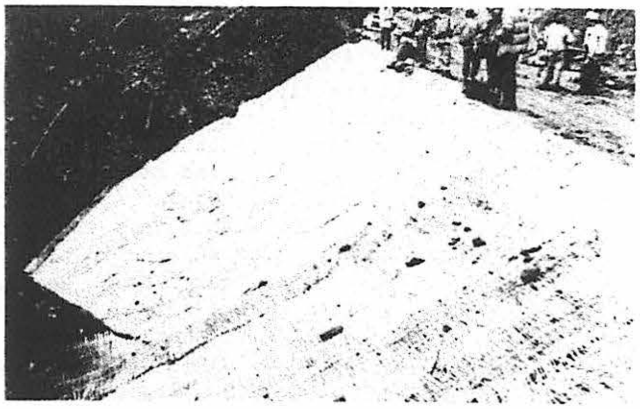

Figure 6.--Slope seeding covered with straw blind.

Cut slope in rocky places are usually left alone, but they are covered with cement mortar reinforced with metal net if there is the possibility of dangerous stone fall in the winter season. The bank slope of the disposal area is also sprayed with mixed grass seeds to protect against rain-wash.

Drainage

The control of both stream water and run-off flowing down the road surface is very important to keep the road base and road surface in good condition. The road surface should be periodically reshaped with a motor-grader to reshape dips. But in Japan, the resources for road maintenance are often not enough to keep forest roads in good condition. Therefore the control of water or the road surface becomes more and more important, especially in view of the high rainfall in Japan.

Various type of open-culverts have been developed and are coming into wide use. They are usually installed at about a thirty degrees angle down grade. They have proved to be very effective for intercepting runnoff flowing down the road surface. The open-culvert on the road sueface might be spaced in accordance with the grade of the road as shown figure 7.

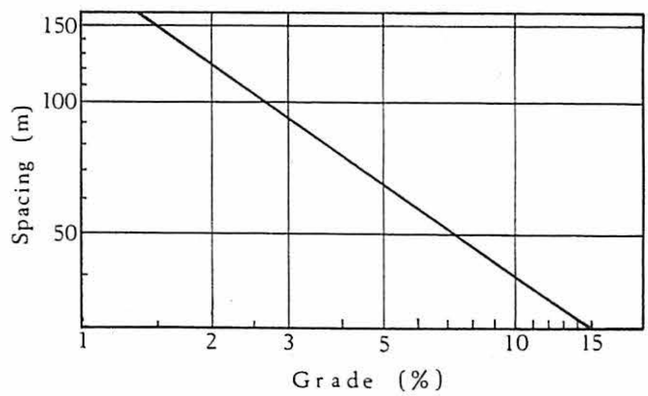

Figure 7.--Spacing standard of the open-culvert on the forest road surface.

LONGITUDINAL GRADE OF ROAD

In order to build up a road network as quickly as possible, it is practical to construct branch roads of a low standard. The standards of road grades at present in force are shown in table 1. This shows that the lower the road standard, the steeper the longitudinal grade of the road which can be adopted. In keeping with such a standard, most low standard roads, which must be in the majority, may be constructed with a steep grade. This results in the erosion of the road surface or the road bed, and land slide of the slope along the route is frequently caused by water flow running down the road surface along wheel dips. This is especially so in places where precipitation is high and terrain is steep. It indicates the necessity to reconsider the standard of the longitudinal grades of forest roads, considering that sixty five percent of damage to forest roads in mountainous areas is brought about by water flow on the road surface.

Low standard forest roads should not only be in low cost but also should be highly resistant to erosion. These conditions will be satisfied by keeping the longitudinal grade gentle for low standard forest roads, for example under five percent. On the other hand, steep grade as are adopted for low standard roads i.e. ten to fourteen percent may be permitted for forest roads of high standard, if necessary because of terrain conditions, and in exchange for using steep grades, the road surface of high standard roads should be paved in order to prevent the erosion or destruction caused by rain-wash on the road surface. Because high standard roads are to be permitted to budget the necessary funds for their construction.

Considering that about ten percent of forest roads with high standard have been paved, the paving of the main forest roads are no longer only a dream, on the contrary, it seems to be an essential treatment for main forest roads from the view point of land protection.

LITERATURE CITED

Iri, Masao and T.Furubayashi. 1976. The theory of graphs. 198p. Nikka-giren Shuppan-sha Co., Tokyo.

Kobayashi, Hiroshi. 1983. Studies on the forest road network planning systems. Bullentin of Utsunomiya University Forest 38: 1 - 101p. College of Agriculture, Utsunomiya University, Utsunomiya.

Minamikata, Yasushi. 1977. On the essential road network to forestry and forest conservation. Journal of Japanese Forestry Society 59(8): 298 -300p. Faculty of Agriculture, University of Tokyo, Tokyo.

Minamikata, Yasushi. 1983. Optimum location of forest roads with computer. An interim report of forest environment assessment for large scale forest roads, Forest Development Corporation : 32 - 41p. University of Tokyo,Tokyo.

Minematsu, Hirohiko and Y. Minamikata. 1983. Optimum spacing for open-top culvert on forest roads. Journal of J.F.S. 65(12): 465 - 470p. Tokyo University of Agriculture and Technique, Tokyo.

INTERACTION OF HARVESTING AND STAND ESTABLISHMENT IN HARDWOODS IN EASTERN NORTH AMERICA[1]

John C. Lees[2]

Abstract.—Harvesting methods affect the ease or difficulty of subsequent hardwood forestation. The trend in eastern North America is to clear-cutting and mechanization. There are problems associated with the existing, often decrepit hardwood forest and the new forest for the next rotation, and with a seeming overabundance of natural regeneration to less valuable species. New designs for logging equipment are required if thinning and shelterwood systems are prescribed.

INTRODUCTION

Silviculture is the art and science of growing trees in forests to fulfill a management objective. Harvesting is a silvicultural treatment that usually meets such an objective and yields a wood product. Other objectives that may be met are improvement of wildlife habitat, salvage of damaged stems, control of snowmelt, creation of recreation opportunities such as skiing and hiking, and wood fibre production.

In production forestry, when the object of management is a sustained yield of wood products, harvesting methods interact most importantly with the relative ease or difficulty of stand establishment and reestablishment. Delays are costly. Instant forestation is the ideal, so that the annual allowable cut effect may be applied and more mature merchantable timber cut. When considering hardwood harvesting in the mainly mixed forests of eastern North America, an understanding of ecological succession and the silvics of species (pioneer, successional, and climax) permits certain predictions about stand establishment to be made, and to be made confidently.

In industrial forestry, and to a lesser extent in private nonindustrial forestry, the harvesting method of choice is clear-cutting, whether in large blocks, small patches, or strips (Marquis 1965). What is not merchantable is left standing, cut and left lying, or moved to trailside or landing and left lying. These residues from harvesting interact with stand establishment.

In general, it can be predicted that

1. Cutover hardwood and mixedwood stands will regenerate naturally to a higher proportion of pioneer (intolerant) hardwoods.
2. In the altered state of a clear-cut, advance growth regeneration will begin a recovery from logging damage.
3. Sprouting species will regenerate from cut stumps and root suckers.
4. Sprouts and surviving advance growth seedlings will dominate the regeneration scene at first.
5. Viable seed stored in the organic soil layers will germinate.
6. Light seed will be dispersed from the uncut stand margin and from standing residuals.
7. Heavy seed will be dispersed on the uncut stand margin and under standing residuals.
8. Competing ground vegetation will proliferate vegetatively and then from seed.
9. Aggressive pioneer species quickly invade unoccupied areas. Successional and climax species, which are nonsprouting and not present in the surviving advance growth, will follow later.

There should be no mysteries here. These sorts of predictions can also be made for forest types on the other side of the world. The silvics of the species harvested and to be reestablished, (table I) interact with stand establishment. This information from Leak et al. (1969), for example, would be a useful prediction tool in this region. It was collected for use in a guide to the silviculture of the northern hardwoods and forms the basis of the guide as modified for Maritime woodlot owners (Lees and Embree 1983).

Harvesting methods change as advances are made in forest engineering technology. The trend in the Northeast is to greater mechanization and to shorter rotations. The new hardwood forest will be managed as if it were a plantation, but the old hardwood forest still creates many harvesting problems. (Today's new felling head on a mechanical harvester may be on tomorrow's scrap

[1] Paper presented at the conference COFE/IUFRO - 1984. Maine, USA and New Brunswick Canada, 12-18 August.

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Table 1. Silvical characteristics of the important species in the beech-birch-maple and associated types*

Species	Shade tolerance	Relative growth rate	Seeding frequency, good crops	Effective[1] seed dispersal	Minimum seedbed requirements	Sprouting vigor	Delayed germination
			Years	Tree heights			
Sugar maple	Tolerant	Medium	2-5	2-3	Light litter	Moderate	Possibly a small proportion
American beech	Tolerant	Medium	2-3	0-1	Light litter	Abundant root suckers	None known
Yellow birch	Intermediate	Slow to medium	2	2-4	Mineral soil or mixed mineral-humus	Very low	None known
Paper birch	Intolerant	Fast	2	2-4	Mineral soil or mixed mineral-humus	Moderate to low	None known
White ash	Intermediate	Medium to fast	3-5	2-3	Light litter	Moderate to high	Up to three-fourths germinate second spring
Red maple	Intermediate	Medium to fast	1	2-3	Light litter	Very high	Small proportion germinate second spring
Aspen	Intolerant	Fast	4-5	-	Continuous moisture	Abundant root-suckering	None
Red spruce	Tolerant	Medium	3-8	2-4	Moist humus or mineral soil	-	None known
Eastern hemlock	Tolerant	Medium	2-3	2-4	Moist humus or mineral soil	-	None known

[1]Effective seed dispersal means that roughly 50 to 75 percent of the seed falls within the given distance.

*Reproduced from "A silvicultural guide for northern hardwoods in the Northeast" with permission of the authors (Leak et al.).

heap, and the harvester retooled as a self-loading forwarder.)

In the Canadian Maritime Provinces, Rowe (1972) describes 13 Forest Sections of which 11 have an important hardwood component. Hardwoods comprise one-third of the forest resource. In New Brunswick, there are about 170 million m^3 of hardwoods (Baskerville 1976[3]) with a theoretical annual allowable cut of 2.8 million m^3 of which only 45% is currently harvested. In Nova Scotia, there are 75.6 million m^3 of hardwood of which only 40% of the annual allowable cut is currently harvested. Hardwoods occur in predominantly mixedwood cover types which when logged for softwood production tend to regenerate to the increasing proportion of pioneer hardwoods previously mentioned. Thus, while Maritime hardwoods are underutilized, quality is rapidly declining and softwood and hardwood managers are now faced with increasing areas of decrepit high-graded hardwood, damaged hardwood residuals, and increasing areas of vigorous pioneer hardwoods, many of stump sprout origin.

Lack of orderly use of the hardwood forest for production, protection, and amenity in the Maritimes; low demand levels; unreliability of markets; distance between quality hardwood use and quality hardwood producers, or between low quality hardwood use and pulpwood stands are recurring features of problem analyses (West 1976[4]; Lees 1982). Short-term production demands are unpredictable. Short-term utilization trends of even the traditional quality forest products

[3]Baskerville, G.L. 1976. Hardwood research in the Maritimes. Unpublished manuscript. Maritimes Forest Research Centre, Canadian Forestry Service, Fredericton, N.B.

[4]West, R.C. 1976. The New Brunswick hardwood problem. Report to Maritime Section, Canadian Institute of Forestry, (Unpublished). 8p.

depend on widely fluctuating markets, transportation costs, and costs of woods operations. Long-term demands can be ranked with only vague predictions of unprecedented world consumption of hardwood products and the sustained importance of quality. Better markets would mean more complete utilization, a better integrated woods operation, and better silviculture. There are management and silvicultural problems associated with the existing, slow growing hardwood forest and also with the new forest to be established for the next and future rotations.

Research and development work now underway in eastern North America includes those problems of utilization of logging residues, natural regeneration responses to complete clear-cutting, and growth responses of hardwoods to juvenile spacing and fertilizing of overdense natural sapling stands.

Logging Residues

In a review of literature about hardwood silviculture and management, it was reported (Lees 1978),

> "The hardwood logging residue following conventional hardwood sawlog operations in the Appalachians is described in a case-study by Craft (1976). His example will serve to illustrate the sorts of materials generated by conventional logging in hardwoods:
>
> After the merchantable timber (12 inches dbh and over) was felled and removed, a typical acre within the 18-acre sample block was selected for close study. The first treatment was the removal of all topwood residue. All sound material that would give a straight or nearly straight piece at least 6 inches in diameter by 4 feet 3 inches long or longer was removed and decked for sawing. The remaining topwood material was stored for chipping. The second treatment was the felling and skidding of all residual trees that were 6 inches diameter at breast height or larger. The final treatment was the felling and skidding of all trees below 6 inches dbh which were weighed and piled for chipping. The total weight of all residues recovered from one acre was 69.3 tons! Topwood residue yielded 11 tons of sawable logs. Residual trees yielded 14.9 tons of sawable bolts and the weight of merchantable logs harvested from the 18 acre unit was about 40 tons per acre. Thus, for every ton of merchantable logs harvested about 1.8 tons of residue remained. The test sawing operation produced 8.2 tons of chippable slabs and edgings and 2.6 tons of sawdust. The chip yield was not assessed."

The problem of generating logging residue in hardwood and mixedwood stands is so serious that Martin (1976) prepared a logging residue yield table. Martin reports that the independent variables i.e., type of cut, products removed, basal area per acre, and stand age explain 95% of the variation in residue volume per acre. The yield table was prepared to show the probable residue volumes for different cutting practices at various levels of residual basal area, and stand age.

Logging residues are also being studied in New Brunswick by B.S. Chisholm, Valley Forest Products, and G.D. van Raalte, Maritimes Forest Research Centre (1980). Four logging intensities have been sampled

(a) Koehring feller forwarder (no clean-up)
(b) Koehring feller forwarder (clean-up)
(c) Conventional cut and skid (no clean-up)
(d) Koehring feller forwarder + conventional cut and skid oversize hardwood and softwood (clean-up) (table 2).

Table 2. Summary of logging production and costs

Treatment	Production	Cost/tonne
(a)	419.7 tonnes (chips)	$ 7.44
(b)	424.7 + 8.4 tonnes (chips)	8.26 + 13.92 (clean-up)
(c)	319.2 tonnes (round wood)	6.95 + 3.70 (estimated chipping cost)
(d)	367.7 + 22.9 tonnes (hardwood round wood) + 14.5 tonnes (softwood round wood)	7.99 + 12.57 + 4.50 + 13.61 (clean-up)

Clean-up (b) $13.92 and (d) $13.61 was costly. Because the roadside chipper has a screen for twigs, leaves, and loose bark, this discarded material was measured for one vanload of chips. It amounted to about 5% of the total feed. This is a significant proportion of the total biomass produced on these hardwood sites, and lost through processing in this way.

Regeneration Responses

My silvicultural studies in the Canadian Maritime Provinces include some examples of the sorts of interactions with which we are concerned today. Contemporary industrial clear-cuts were sampled beginning in 1977. When 10 clear-cuts were assigned to three original stand types; i.e. shade tolerant hardwoods, intermediate, and shade, intolerant, a large proportion of the natural regeneration (25-90%) was composed of the less valuable pioneer and successional species such as red maple, grey and white birch, and poplar (table 3).

A further examination of this regeneration in 10, 4-m^2 quadrats under the uncut stand, on the stand margin, and in the open clear-cut showed significant ($\underline{P} = \leq 0.05$) differences in numbers and origin. Regeneration of the more valuable shade tolerant sugar maple, ash, and beech in the open was mainly vegetative, (fig. 1). The heavy-seeded sugar maple germinated on the stand margin, the light-seeded birches also in the open, and red maple and white ash were intermediate.

Regeneration responses to pulpwood logging systems at Pokiok, N.B. are compared in table 4.

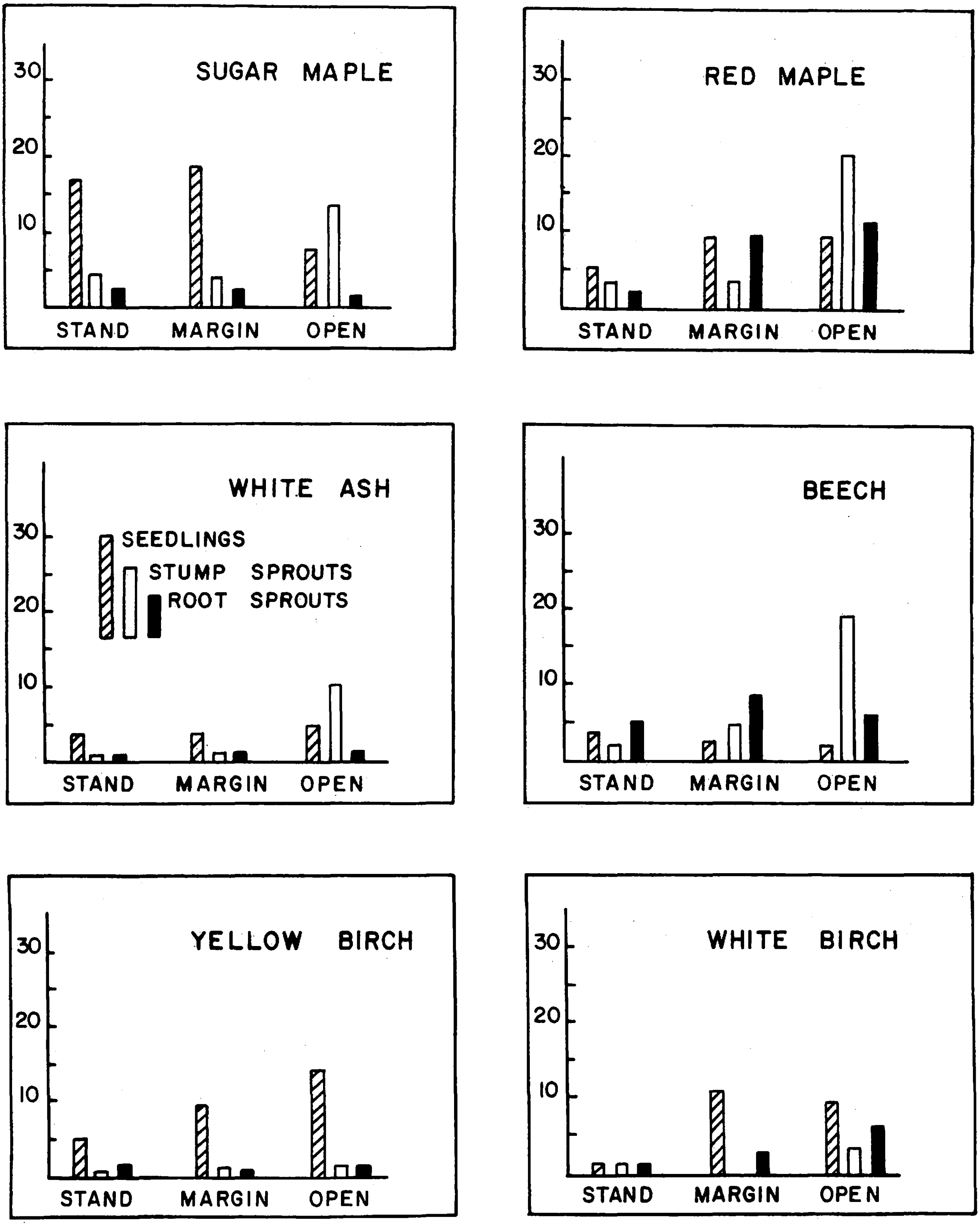

Figure 1. Number of stems and their origin per 40-m² transect (0.004 ha).

Table 3. Proportions of regenerating species (percentages)

Stand type	Location	Sugar maple	Red maple	Yellow birch	White birch	White ash	Beech	Poplar	Grey birch	Black ash	Total
Tolerant	Nashwaak	3	40	7	8	20	17	1	-	4	100
	St. Croix	18	8	29	1	8	29	2	-	5	100
Intermediate	Crowhill	8	21	15	36	-	20	-	-	-	100
	Acadia	-	59	-	22	-	-	-	19	-	100
Intolerant	Coles Island	-	73	-	1	-	-	16	10	-	100
	Anagance	-	40	-	-	-	-	27	33	-	100

Table 4. Percentage composition of natural regeneration by species and sprouts, Pokiok, N.B. June 1979 (n, 100 4-m² quadrats)

	Harvesting system			
	Conventional chainsaw cut		Koehring machine cut	
	%		%	
Species	Regen.	Sprouts	Regen.	Sprouts
Sugar maple	2	100	10	95
Red maple	51	44	20	93
Yellow birch	3	44	5	60
White birch	18	15	23	58
Beech	-	-	10	92
Poplar	1	25	4	8
Softwoods	20	-	5	-
Pin cherry	6	-	23	-
All	100	28	100	54

A Koehring feller-forwarder produced a 54% sprout regeneration component after two years, the conventional chainsaw-and-skidder operation only 28%.

On another Valley Forest Products Koehring operation at Napadogan, N.B. a sample of 30 stems were chainsaw-cut and paired with machine-cut stumps. Subsequent red maple stump sprouting was monitored for six years, to 1982, and is illustrated in figures 2-4. The sprout drop-out rate for both chainsaw and machine-cut stumps is now stable, but early differences were the cause of some concern. Mean values (1984) are

	No. sprouts per stump	Height tallest	Diameter tallest
		cm	cm
Chainsaw-cut	17	95	3.2
Machine-cut	18	260	3.2

Height differences are now attributed in large measure to deer browsing.

Logging Damage

A logging damage study is underway in advance growth seedlings on a conventional chainsaw-and-skidder operation in mixed northern hardwoods near Canterbury, N.B. One hundred 4-m² quadrats in units of 10 were examined before and after logging in summer and fall 1982. The tallest seedling of each species in each quadrat was marked on the ground before logging began and mapped as the seedling most likely to survive. Logging resulted in several changes in seedbed and slash cover. Four slash types, degrees of cover, and disturbance type were recognized. The commonest condition was skidding disturbance (26%), with a light (50%), hardwood (47%), slash cover. However, 62% of the 100 quadrats were undisturbed by skidding or slash redistribution. Mortality because of drying out of the organic soil layers was common. Many sugar maple seedlings with only 2-4 leaves, on undisturbed sites did not survive the increased exposure following logging. Of the 375 identified tallest seedlings only 103 survived the logging operation. Of the 272 losses;

48% were "missing,"
12% were "dried out,"
10% were "smothered in slash,"
28% were "skidded over," and
2% were "damaged in felling."

Eighty-seven percent of the losses were in the height range 0-50 cm.

The results of these and other studies are provided to the Cutover Response Subcommittee and the Hardwood Technical Committee of the New Brunswick Forest Research Advisory Committee, and to the Hardwoods Working Group of the Nova Scotia Forest Research Committee. In this way it is hoped to fine-tune predictions of the interaction of harvesting and stand establishment. A minimum acceptable height class of advance growth seed lings should be determined.

Logging and Season of the Year

The timing of harvest cutting affects hardwood regeneration. Some species disperse seed earlier in the summer (red maple), others later (sugar maple), and some throughout the fall and winter (white birch). Summer logging may inhibit stump sprouting while winter logging may produce more vigorous sprouts and suckers from reserves stored in the roots at that time.

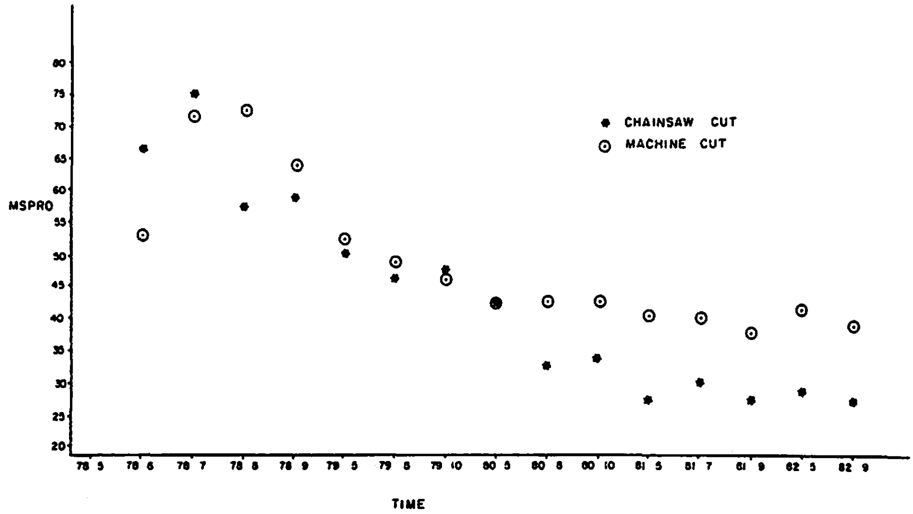

Figure 2. Mean number of sprouts per cut stump, over time.

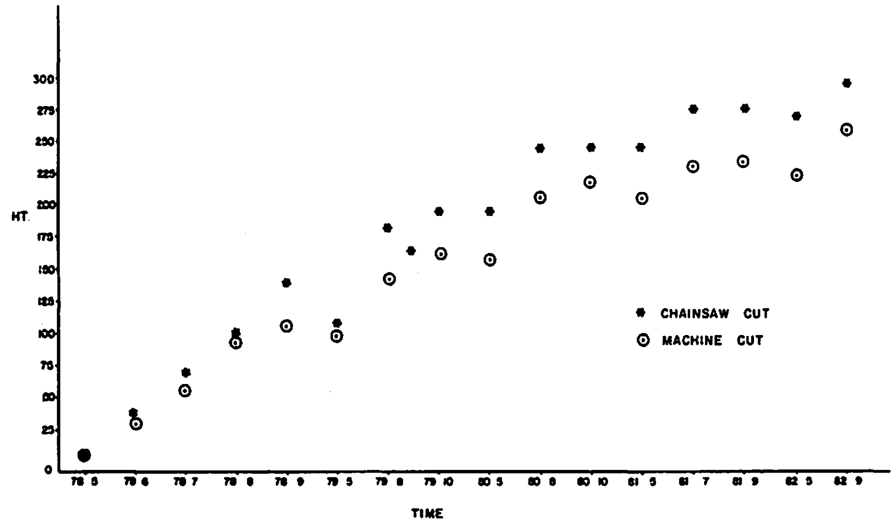

Figure 3. Mean height of tallest sprout per cut stump, over time.

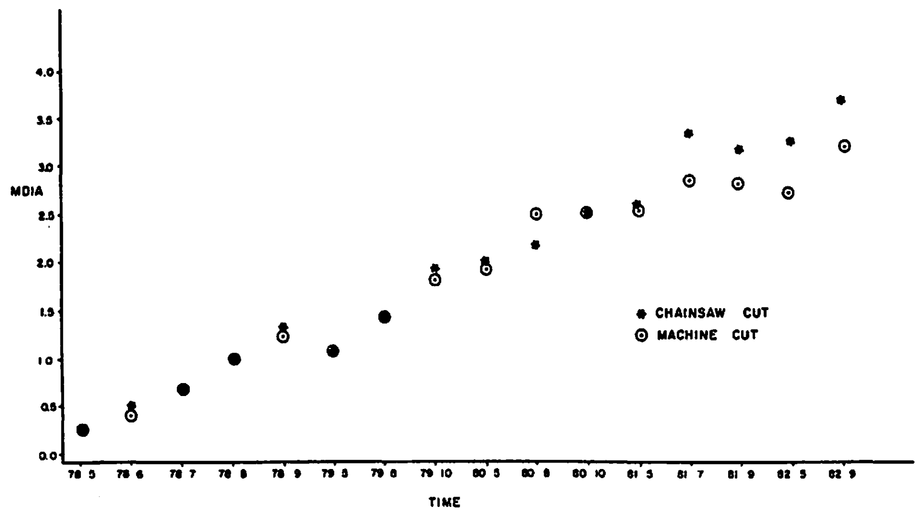

Figure 4. Mean diameter of tallest sprout per cut stump, over time.

Tubbs and Reid (1984) report that winter logging in northern hardwood stands resulted in better stocking to seedling sugar maple, yellow birch, and white birch. Summer clear-cuts were not well stocked with birch, and maples increased proportionately so that all cutover areas were fully stocked. Seed-trapping studies in Nova Scotia and New Brunswick on birch seed-tree areas and strip clear-cuts confirm the phenology of seeding of these species and may support Tubbs and Reid's observation of seed dispersal under a shelterwood, degree of seedbed disturbance, and season of logging.

DISCUSSION

Where such predicted responses to clear-cutting are unacceptable, alternative harvesting methods may be prescribed. Alternative stand establishment treatments may also be required. The problems are those of a seeming overabundance of natural hardwood regeneration to less valuable species. This creates a need to manipulate the proportions of species and their origin (sprout or seedling).

The valuable, denser-wooded tolerant hardwoods (sugar maple, yellow birch, ash), often require a shelterwood for reestablishment. The shelterwood systems developed by Tubbs and Metzger (1969) for birch in the Lake States are now commonly prescribed for mixed northern hardwoods in the New England States and Nova Scotia. The selection system, at first applied to tolerant hardwoods in Ontario, may be attractive to the small private woodlot owner in the Northeast and suitable for beech-maple types in Quebec and the Maritimes. Narrow strip clear-cutting is chosen in some regions of Quebec, Maine, Nova Scotia, and Prince Edward Island to obtain satisfactory regeneration of more tolerant species.

The implications for harvesting equipment development, of management trends to thinning, and "partial cutting" are far-reaching. A new generation of small maneuverable machines will be needed. The private nonindustrial forest manager (and there are thousands of them in every jurisdiction in the Northeast) will ensure a market for such harvesting equipment, but what will be the impact on advance growth, seedbed, planting site, and ground vegetation competition?

These new harvesting systems will clearly interact with stand establishment costs. Research and development trials, field demonstrations, and economic analyses are now due.

LITERATURE CITED

Chisholm, B.S., and G.D. van Raalte, 1980. Biomass harvesting in a tolerant hardwood stand in central New Brunswick. Can. For. Serv., Marit. For. Res. Cent. Inf. Rep. M-X-111.

Craft, E.P. 1976. Utilizing hardwood logging residue: A case study in the Appalachians. USDA For. Serv. Res. Note NE-230. 7p.

Leak, W.B., D.S. Solomon, and S.M. Filip. 1969. A silvicultural guide for northern hardwoods in the Northeast. USDA For. Serv. Res. Pap. NE-143. 34p.

Lees, J.C. 1978. Hardwood silviculture and management: An interpretive literature review for the Canadian Maritime Provinces. Can. For. Serv., Marit. For. Res. Cent., Inf. Rep. M-X-93 69p.

Lees, J.C. (ed.) 1982. Fuel or fiber? Hardwood utilization and marketing opportunities. Can. For. Serv., Marit. For. Res. Cent. Inf. Rep. M-X-138. 39p.

Lees, J.C., and D.G. Embree 1983. New England hardwood stocking guides should work for Maritime woodlot owners. Can. For. Serv., Marit. For. Res. Cent. Tech. Note 85. 7p.

Marquis, D.A. 1965. Controlling light in small clearcuttings. USDA For. Serv. Res. Pap. NE-39. 16p.

Martin, A.J. 1976. A logging residue "yield" table for Appalachian hardwoods. USDA For. Serv. Res. Note. NE-227. 3p.

Rowe, J.S. 1972. Forest regions of Canada. Dep. Environ., Can. For. Serv. Publ. 1300. 172p. + map.

Tubbs, C.H., and F.T. Metzger. 1969. Regeneration of northern hardwoods under shelterwood cutting. For. Chron. 45: 333-337.

Tubbs, C.H., and B.D. Reid. 1984. Logging season affects hardwood reproduction. North. J. Appl. For. 1:5-7.

Species names

American beech	_Fagus grandifolia_ Ehrh.
Eastern hemlock	_Tsuga canadensis_ (L.) Carr.
Grey birch	_Betula populifolia_ Marsh.
Largetooth aspen	_Populus grandidentata_ Michx.
Pin cherry	_Prunus pensylvanica_ L.f.
Red maple	_Acer rubrum_ L.
Red oak	_Quercus rubra_ L.
Red spruce	_Picea rubens_ Sarg.
Sugar maple	_Acer saccharum_ Marsh.
Trembling aspen	_Populus tremuloides_ Michx.
White ash	_Fraxinus americana_ L.
White birch	_Betula papyrifera_ Marsh.
White elm	_Ulmus americana_ L.
Yellow birch	_Betula alleghaniensis_ Britton

INTERACTION OF HARVESTING AND STAND ESTABLISHMENT IN CONIFERS IN NORTHEASTERN NORTH AMERICA[1]

Maxwell L. McCormack, Jr.[2]

Abstract.--Harvesting systems in spruce-fir forests have been primarily dependent on advanced regeneration. Minimum disturbance of sites is important to reduce disruption of drainage and establishment of undesirable vegetation. Trends toward mechanical full-tree harvesting are causing problems of soil disturbance, logging residue reduction, and nutrient removals.

INTRODUCTION

The northeastern conifer forest occurs on shallow glacial till soils, often with a compact layer at 40 to 60 cm which impedes drainage and root development. Many sites have relatively poor drainage resulting in very high organic matter content and excessive moisture. Irregular terrain, numerous drainage channels, and boulders often impede harvesting. Many sites are relatively flat and favor mechanical harvesting. In some regions fire has been a significant natural disturbance.

Silvical characteristics (Fowells 1965) and silvicultural systems (U.S. Department of Agriculture 1983) for major conifer species (Table 1) have been summarized. A silvicultural guide for spruce-fir (Frank and Bjorkbom 1973) is available. Most past management has been dependent on natural regeneration with interest in plantation culture, requiring some site preparation, developing in recent years. Advanced regeneration of the spruces and fir establishes readily in partially shaded understory conditions. However, the short-needled species are sensitive to exposure during the post-harvest establishment stage and need good conditions for satisfactory early growth. Pine and fir seed crops are fairly regular and reliable; those of the spruces are intermittent with limited dispersal. No significant viable seed is stored in the duff layers.

Pines may seed in effectively following harvest, but successful spruce-fir regeneration must be established before the overstory is removed. Where there is unsatisfactory stocking of spruces, those species are reestablished best by planting immediately after harvesting. Evenaged management is the rule, but spruce-fir stands can also be managed under the selection system (Frank and Blum 1978).

The spruce budworm [*Choristoneura fumiferana* (Clemens)] has made an impact on this forest. Defoliation of dominant trees, mortality of fir, reduced seed crops, and establishment of undesirable vegetation in defoliated stands have complicated harvesting operations and scheduling. There are very few pure stands except on poor sites and in plantations. Consequently, postharvesting conditions usually include a period of development by aggressive pioneer broadleaf vegetation which interferes with conifer regeneration, especially on good sites. Species which pose serious problems include red raspberry (*Rubus idaeus* L.) which forms a dense uniform cover. Red maple (*Acer rubrum* L.) and mountain maple (*A. spicatum* Lam.) are vigorous stump sprouters. Aspen (*Populus tremuloides* Michx.) and beech (*Fagus grandifolia* Ehrh.) produce large quantities of root sprouts, and the birches (*Betula papyrifera* Marsh., *B. populifolia* Marsh.) are prolific seeders. Stored seeds of raspberry and pin cherry (*Prunus pensylvanica* L.F.) frequently provide rapidly established cover which excludes conifers. These competitors have been characterized by Leak *et al.* (1969), and Lees[3] provides pertinent insight.

[1]Paper presented at the conference COFE/IUFRO-1984. Fredericton, New Brunswick, Canada, 17-18 August 1984.
[2]Maxwell L. McCormack, Jr. is Research Professor of Forest Resources and Leader, Cooperative Forestry Research Unit, University of Maine, Orono, Maine, USA.

[3]Lees, J.C. Interaction of harvesting and stand establishment in hardwoods in eastern North America. Draft paper prepared for conference COFE/ IUFRO 17-18 August 1984.

Table 1. Selected regeneration characteristics of important conifer species in northeastern North America.

Regeneration method					
Nat.	Plt.	Species	Effective advance regen.	Consistent seed supply	Easy to establish
●	○	Red spruce (<u>Picea rubens</u> Sarg.)	●	◯	◯
●	●	Black spruce [<u>P. mariana</u> (Mill.) B.S.P.]	●	◐	◐
●	◐	White spruce [<u>P. glauca</u> (Moench) Voss]	◐	◯	◐
●	◯	Balsam fir [<u>Abies balsamea</u> (L.) Mill.]	●	●	◐
◐	●	Red pine (<u>Pinus resinosa</u> Ait.)	◯	◐	●
◯	◐	White pine (<u>P. strobus</u> L.)	◐	◐	●
○	◐	Jack pine (<u>P. banksiana</u> Lamb.)	○	◐	●
◯	◐	Tamarack [<u>Larix laricina</u> (DuRoi) K. Koch]	○	◯	◐

○ = Little or no use
◐ = Moderate use and characteristic
◯ = Low use, weak characteristic
● = High use, strong characteristic

Presence of shade tolerant undesirables in the forest understory, combined with their potential for rapid establishment following disturbances, results in an explosion of competing vegetation which effectively prevents conifer establishment or suppresses development of advanced regeneration on the better sites. Partial cuts often result in sufficient ground disturbance to facilitate early establishment of undesirables. The shallow rooting of spruce and fir makes lateral root systems vulnerable to machinery damage and windthrow. Partial cut harvests in older, well-developed stands can, thereby, result in losses of residual, future crop trees and the turned up soil provides seedbeds for advanced development of undesirable species. However, properly timed entries for partial, light removals from below can be successful. Shelterwood cuts, administered in a way to retain the best quality and spacing of residuals, provide good potential for establishing natural regeneration.

HARVESTING SYSTEMS

Years ago, horse logging with water transport was common. A transition has taken place from shortwood to tree-length systems and, more recently, to full-tree removals by large feller-forwarders and in-woods chipping. Different postharvesting site conditions and vegetation dynamics have accompanied this transition. Trials with high lead cable systems have provided some biological advantages, but high costs have deterred their development in the region. As we proceed with equipment development and modification, programs to improve operator knowledge and understanding become an essential component of total harvesting systems.

When considering establishment of the next crop we must consider impacts of mechanical harvesting on the natural systems and consequences of residue redistribution. All appraisals and projections must recognize differences in site quality. Changes in the natural system and subsequent silvicultural needs depend on the extent of harvesting (i.e. partial cuts of various intensities vs. clearcutting) and management objectives for culturing residual stands, or for establishing regeneration naturally or artificially.

Much depends on the characteristics of the stand to be harvested and it is important to anticipate future stand development prior to harvest. Special attention must be given to existing and potential vegetation problems. Also, a careful appraisal of physical site conditions is essential.

Moisture relationships, especially drainage, are critical determinants of site quality. Disruption of drainage patterns in shallow soils by equipment ruts can cause serious, long-lasting damage. Though some benefits to regeneration from full-tree harvesting have been described (Saltarelli 1980), recent trends toward full-tree removals and roadside mechanical delimbing have prompted concerns about harvesting residues and their management. The values of residues fall into three general categories:

(1) Providing desirable microhabitat and protection for seedlings,

(2) Adding organic matter (OM) directly to the soil, and

(3) Composing an important part of the nutrient cycle.

Advanced regeneration of spruce and fir has high value and provides an opportunity to have the next stand in place before final harvest. One of the most valuable assets in the Acadian spruce-fir forests is a bountiful supply of desirable advanced regeneration (Smith 1981). If regeneration in place immediately after harvest is compared to the cost of site preparation and planting, significant efforts to retain natural advanced regeneration are easily justified. Well-distributed slash can play a major role by protecting regeneration from browsing animals, dessication, and frost heaving. Transient shade provides desirable temperature and moisture conditions. Though not quantified in detail, these relationships have been observed over long periods of time.

The loss of natural regeneration can be replaced through intensive planting programs when the necessary investments are made. However, the loss of OM has longer-term implications. OM is a source of N in the surface horizons, but its physical involvement is also very important. OM plays a role in soil bulk density, formation of macropore space, cation exchange capacity, and moisture retention.

More detailed nutrient cycling information which is directly related to specific site conditions is needed. Kimmins (1974) expressed a need to define rotation length in terms of an "ecological rotation" where soils are permitted to return to the preharvest ecological condition. Whole-tree removals break the nutrient cycle by a drastic redistribution of living biomass. This change is not readily remedied by simply replacing the nutrients lost by applying fertilizer.

Bengston (1981) described residue removals in terms of dollar values of the nutrients being removed. The increase in harvest yields through more complete removals have a much higher cost per unit. Some costs are difficult to define. For example, small litter components (branches, leaves, twigs) may serve as important initial sources of nutrients for regeneration. This same basic relationship is thought to benefit residual crop trees from slash remaining after thinnings or shelterwood cuts.

Alleviating nutrient losses by not removing the large nutrient capital in foliage might be accomplished through harvesting techniques which leave foliage on the site. Bjerkelund (1984) has proposed a compromise which would leave valuable nutrient-rich components on the site by employing a "trimmed whole tree" harvest.

STAND ESTABLISHMENT INTERACTIONS

As experience is gained with mechanical systems, valuable lessons are learned. For example, there is better appreciation of the significance of leaving unmerchantable paper birches during a summer mechanical clearcut of spruce-fir. The apparent cost saving becomes a costly expense in regenerating the site to conifers. Timely removals of a prolific, undesirable seed source in the presence of an ideal seedbed would be a judicious move during harvest.

Planned concentration of machine traffic provides residual undisturbed areas. Advanced regeneration can be retained on undisturbed portions while the concentrated machine disturbance provides effective site preparation to be planted immediately after harvest. Bunching of felled stems within feller-buncher trails which are also used by grapple skidders demonstrates how this basic technique can be employed[4]. Lack of disturbance is a desirable feature. It enables advanced regeneration to develop after harvest. Machine disturbance damages, or eliminates, desirable seedlings. Also, it benefits undesirable pioneer brush species.

Observed relationships of harvesting with site and stand conditions are being substantiated through scientific documentation (Case and Donnelly 1979, College of Environmental Science and Forestry 1979, Freedman 1981, Freedman _et al_. 1981, Lyman 1982, Smith 1984a, Weetman and Webber 1972, Weetman and Frisque 1977, Weetman and Algar 1983). Northeastern spruce-fir site conditions were recently appraised on 190 transects comprising 3.6 miles of samples across seven townships in northern Maine[5]. Conditions were studied on sites which had been mechanically clearcut between 1973 and 1982.

Harvesting systems they studied included the use of a large, rubber-tired feller-forwarder; feller-bunchers on rubber tires; and feller-bunchers on lags. Grapple skidder disturbance was an integral part of the feller-buncher systems.

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[4]Observed operational procedures, Georgia-Pacific Corp., Washington Co., Maine, USA.

[5]Unpublished preliminary data. 1983 Maine landowner study of site disturbance by mechanical harvesting equipment.

Table 2 summarizes site disturbances across the study. Surface disturbances were differentiated between those confined to organic layers and those reaching mineral soil. Less than half of the area was left undisturbed.

Table 2. Summary of site disturbance by mechanical harvesting done during 1973-1982[5].

Disturbance classification	Area affected
	---(%)---
UNDISTURBED	47.7
SCARIFICATION	
Organic	12.2
Mineral	1.9
RUTS	
Organic	8.7
Mineral	5.7
SLASH	9.7
OTHER	14.1
TOTAL	100.0

Relatively thorough removal of residues and mechanical delimbing at roadside is reflected by only 9.7 percent of the area covered with slash. Table 3 presents selected results comparing winter and summer harvesting. As expected, there is less disturbance from winter harvesting and a possible additional benefit of more area covered with slash. My observations of mechanical harvests across northern Maine consistently show best development of new spruce-fir stands where

Table 3. Selected comparisons of summer and winter mechanical harvesting during 1973-1982.[5]

Season	Undisturbed	Scarification Organic	Scarification Mineral	Slash
	----------(% of area affected)---------			
Summer	39.3	13.7	2.3	8.3
Winter	66.1	8.9	1.0	12.7

there has been well-distributed slash, especially when harvested during winter. The best young stands were usually attributable to harvests by a Beloit Tree Harvester which delimbed at the stumps and travelled on lags. The landowner study indicated that snow cover alone was not always sufficient as a protection to site. A confounding factor in data collection appears to be distinguishing true winter conditions from the beginning of spring breakup. With respect to the latter, aspect of site appeared to be important.

The three types of equipment involved across the study period are compared in Table 4. Heavier equipment tends to cause deeper ruts than lighter equipment and ruts can cause serious disruption of drainage. Recent trends seem to be toward somewhat lighter, better balanced equipment carried on wider tires.

Table 4. Selected categories of site disturbance by equipment used for harvest in northern Maine during 1973-1982.[5]

Equipment	Un-disturbed	Scarification Organic	Scarification Mineral	Ruts Organic	Ruts Mineral	Slash
	------------% of area affected------------					
Feller-forwarder	35.0	14.3	2.5	8.3	8.2	12.5
Feller-buncher (tires)	25.8	19.5	2.5	9.5	7.9	10.2
Feller-buncher (lags)	66.0	8.5	1.6	9.4	2.9	5.0

Conifer regeneration was growing best on good, undisturbed areas. Disturbance of sites appeared to cause some loss in productivity and, where it disrupted the organic pad, resulted in barren ground which eventually developed into undesirable brush cover rather than useful tree species.

A study initiated in 1979 to evaluate mechanical full-tree removal, residue management and nutrient cycling on a spruce-fir watershed (Smith 1984a, 1984b) indicates trends similar to data from other studies in the region (Freedman _et al._ 1981, Weetman and Webber 1972). An intensive evaluation was made of harvested biomass and nutrient content. Soil solutions have been sampled on a regular schedule to monitor the active nutrient cycle.

In evaluating the disposition of residues, the distribution of biomass within merchantable trees is important. Table 5 shows a typical breakdown for a merchantable red spruce. Considering green organic matter benefits and nutrient values of residues, it is important to note the proportion of the tree in small branches and foliage. The harvesting system studied involved mechanized roadside delimbing which resulted in residues piled at the landings. The

Table 5. Biomass distribution for a red spruce in north central Maine, b.h. age = 112, dbh = 33.6 cm, total height = 19.3 m, live crown ratio = 44% (Smith 1984b).

Component	Oven dry weight	%
	(kg)	
BRANCHES		
<0.25" + Foliage	47.35	11.0
0.25 to 1"	15.47	3.6
1 to 3"	16.94	3.9
Dead	32.60	7.6
TOP (4" Merch.)	2.91	0.6
MERCH STEM	312.92	73.1
TOTAL	428.19	

fact that these residues were removed from the site is important. Estimated amounts per unit of land area are in Table 6.

Table 6. Estimated above-ground biomass for a harvested spruce-fir stand in north central Maine (Smith 1984b).

Stand Component	Oven dry weight	
	Metric	English
	(T/ha)	(T/a)
Preharvest (trees)	230	102
Harvest removal	209	93
Merchantable material	152	68
Roadside residue	57	25

Three residue management alternatives were applied on the treated watershed:

(1) Complete removal of residues;
(2) Residues chipped and scattered, and
(3) Residue scattered intact on the site.

Porous cup lysimeters at depths of 25 cm and 50 cm have been used to obtain soil solution samples. Nitrate (NO_3) concentrations before and immediately after harvest are illustrated in Figure 1. Three seasons later, concentrations have returned close to preharvest levels. Soil

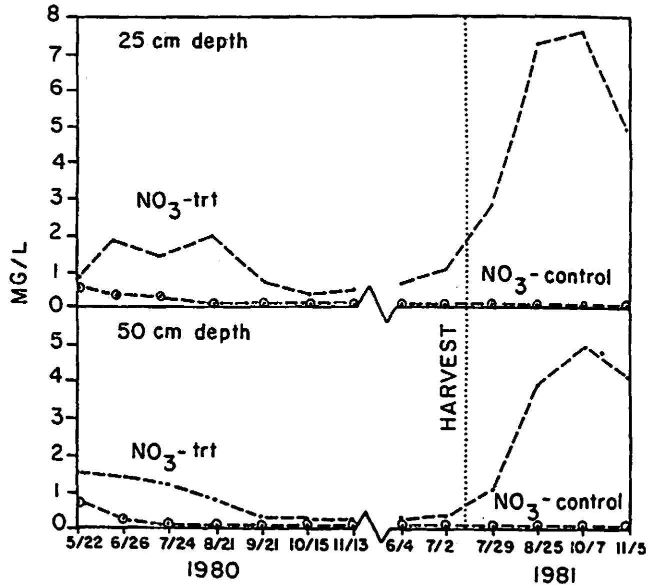

Figure 1. Nitrate (NO_3) concentrations of soil solutions collected from two depths before, and immediately after, clearcutting a spruce-fir watershed in north central Maine Maine (Smith 1984a).

drainage classes were more important than residue treatments (Table 7). This emphasizes the need to consider site characteristics carefully. Most of the NO_3 change following harvest took place on the better drained locations. As expected, a more dynamic situation exists on the better sites.

Table 7. Soil solution nitrate concentrations by soil drainage class, three months after clearcutting a spruce-fir watershed in north central Maine (Smith 1984a).

Sample depth (cm)	Soil drainage class		
	Moderately well (N=4)	Poorly to somewhat poorly (N=8)	Average all plots (N=12)
	NO_3 (mg/l)		
25	18.36	0.18	7.76
50	12.3	0.12	5.12

This same clearcut watershed study measured nutrient quantities and removals in a spruce-fir full-tree harvest. Using tree component data, comparisons can be made between full-tree and bole-only harvests (Table 8).

Table 8. Estimated soil nutrient reserves and harvest removals for a spruce-fir stand in north central Maine (Smith 1984b).

	N	P	K	Ca	Mg
	(kg/ha)				
FOREST FLOOR PLUS MINERAL SOIL (54 cm) NUTRIENT POOLS					
Total[1]	6709	2770	10063	10668	36483
Exchangeable[2]	--	217	159	392	211
HARVEST REMOVALS					
Whole tree	322	46	192	423	44
Bole only	98	12	94	215	17

[1]Technicon block digest for N and P; nitric-perchloric extractable K, Ca, Mg.

[2]1N NH_4 OAc, pH 7.0, extractable K, Ca, Mg; Bray-Kurtz extractable P.

When examining the data as ratios of nutrient reserves to harvest removals (Table 9), it is possible to speculate on available nutrients for future rotations. This study (Smith 1984b) estimated roadside residues to be equivalent to 13 percent of extractable Mg, 16 percent of exchangeable P, 53 percent of exhangeable Ca, and 61 percent of exchangeable K. If these nutrients were to be replaced by fertilizing, increased yields through harvesting branches and foliage result in relatively high per-unit costs for the additional biomass removed. The nutrients in the residues could help to replenish the exchangeable soil nutrients as they are released through decomposition.

Table 9. Estimated ratios of nutrient reserves to harvest removals (i.e. number of rotations to deplete total or exchangeable soil nutrient reserves without additions of nutrients from other sources) for a spruce-fir stand in north central Maine (Smith 1984b).

	N	P	K	Ca	Mg
	(ratios)				
TOTAL NUTRIENT RESERVES					
Whole Tree	21	60	52	25	829
Bole Only	68	231	107	50	2146
EXCHANGEABLE NUTRIENT RESERVES					
Whole Tree	--	5	0.8	0.9	5
Bole Only	--	18	1.7	1.8	12

Nutrients could be conserved on sites where they are needed by removing only merchantable stems, since full-tree harvests removed two to four times as many nutrients as a bole-only harvest would have.

SUMMARY

Harvesting systems in northeastern conifer forests have been primarily dependent on natural regeneration. Successful spruce-fir regeneration must be established before the overstory is removed. Harvesting systems should result in minimal site disturbance and the maintenance of advanced regeneration. Where necessary, planting should be done as soon after harvesting as possible.

Especially on good sites, postharvesting conditions usually result in dense growth of undesirable broadleaf vegetation which requires silvicultural consideration. Physical site conditions must be carefully appraised before operations are initiated. Properly timed and executed shelterwood cuts provide good potential for establishing effective advanced regeneration of spruce and fir.

Trends toward mechanical full-tree harvesting are causing problems concerning soil disturbance, logging residue distribution, and nutrient cycling. Disturbed soil surfaces can disrupt drainage and provide seedbeds which benefit regeneration of undesirables. Removal of residues, such as small branches and foliage, from sites results in loss of beneficial microhabitat for desirable seedlings, lost benefits to soils from organic matter additions, and nutrient removals.

Exchangeable nutrient reserves are depleted more by full-tree harvests of spruce-fir than by bole-only harvests. The availability of adequate quantities of Ca and K for a subsequent rotation is questionable. Conservation of nutrients and benefits to regeneration through use of harvesting systems which leave nutrient-rich residues distributed across sites is recommended.

LITERATURE CITED

Bengston, G.W. 1981. Nutrient conservation in forestry: A perspective. So. Jour. Applied Forestry 5:50-59.

Bjerkelund, T.C. 1984. Trimmed whole tree forest operations: Several concepts for the near future. UNB Forestry Focus 9(1). Faculty of Forestry, Univ. of New Brunswick, Fredericton, N.B., Canada.

Case, A.B., and J.G. Donnelly. 1979. Type and extent of ground disturbance following skidder logging in Newfoundland and Labrador. Information Report N-X-176. 25 p. Newfoundland Forest Research Centre, St. John's, Newfoundland.

College of Environmental Science and Forestry (A.L. Leaf, Editor). 1979. Proceedings, Impact of intensive harvesting on forest nutrient cycling. State University of New York, Syracuse, New York. 421 p.

Fowells, H.A. 1965. Silvics of forest trees of the United States. Agriculture Handbook No. 271. 761 p. USDA Forest Service, Washington, D.C.

Frank, R.M., and J.C. Bjorkbom. 1973. A silvicultural guide for spruce-fir in the Northeast. General Technical Report NE-6. 29 p. USDA Forest Service, Upper Darby, Pennsylvania.

Frank, R.M., and B.M. Blum. 1978. The selection system of silviculture in spruce-fir stands --procedures, early results, and comparisons with unmanaged stands. Research Paper NE-425. 15 p. USDA, Forest Service, Broomall, Pennsylvania.

Freedman, B. 1981. Intensive forest harvest: A review of nutrient budget considerations. Information Report M-X-121. 78 p. Maritimes Forest Research Centre, Fredericton, N.B., Canada.

Freedman, B., R. Morash, and A.J. Hanson. 1981. Biomass and nutrient removals by conventional and whole-tree clear-cutting of a red spruce-balsam fir stand in central Nova Scotia. Canad. Jour. For. Res. 11:249-257.

Kimmins, J.P. 1974. Sustained yield, timber mining, and the concept of ecological rotation, a British Columbian view. For. Chron. 50:27-31.

Leak, W.B., D.S. Solomon, and S.M. Filip. 1969. A silvicultural guide for northern hardwoods in the Northeast. Research Paper NE-143. 34 p. USDA Forest Service, Upper Darby, Pennsylvania.

Lyman, M.W. 1982. The effects of whole-tree harvesting on nutrient supplies and nutrient cycles in a forest ecosystem: A literature review. National Woodlands, Nov-Dec pp. 11, 12, 18, 19.

Saltarelli, N. 1980. Better regeneration through full tree logging. Pulp & Paper Canada (reprint from June issue).

Smith, C.T., Jr. 1984a. Intensive harvesting, residue management alternatives and nutrient cycling in the spruce-fir [*Picea rubens* Sarg. - *Abies balsamea* (L.) Mill.] Type: The Weymouth Point Study. Progress Report 26. 42 p. Cooperative Forestry Research Unit, Univ. of Maine, Orono, Maine.

Smith, C.T., Jr. 1984b. Nutrient removals and soil leaching from a whole-tree harvest of a red spruce (*Picea rubens* Sarg.) balsam fir [*Abies balsamea* (L.) Mill.] stand in north central Maine. Ph.D. Dissertation. Univ. of Maine, Orono, Maine. 214 p.

Smith, D.M. 1981. The forest and Maine's future. Proc. of the Blaine House Conference on Forestry. Augusta, Maine 21-22 Jan. pp. 79-87.

U.S. Department of Agriculture, Forest Service. 1983. Silviculture systems for the major forest types of the United States. Agriculture Handbook No. 445. 191 p. USDA Forest Service, Washington, D.C.

Weetman, G.F. and B. Webber. 1972. The influence of wood harvesting on nutrient status of two spruce stands. Canad. Jour. For. Res. 2:351-369.

Weetman, G.F., and G. Frisque. 1977. Reproduction patterns and species dominance ten years after pulpwood harvesting. Pulp & Paper Canada 78(9):78-84.

Weetman, G.F., and D. Algar. 1983. Low-site class black spruce and jack pine nutrient removals after full-tree and tree-length logging. Canad. Jour. For. Res. 13:1030-1036.

HARVESTING FULL TREES IN THINNINGS

- SHOULD THE LOGGING RESIDUE BE REMOVED?

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Abstract.--Some companies are today harvesting full trees in thinnings. In a short-team perspective this method offers certain advantages; in the long term, the scientists do not know for sure. There is, however, a definite trend. Certain losses of increment of growing stock apparently can be expected if the logging residue is not left on the ground. This is what Sven-Olof Andersson concludes in the following account of investigations made by himself and other Nordic scientists.

INTRODUCTION

Logging of full trees in thinnings has been practiced by a number of Swedish companies for some years. This method can be profitable on a short term basis. The yield is larger compared to thinnings where only industrial roundwood is utilized. The economic outcome of the thinnings will also be more favourable. One important question remains however, how will the growth be influenced by the fact that no slash is left on the ground?

NORWEGIAN PILOT TRIAL

As early as 1928 a pilot study was made in Norway to find an answer to this question. A sample plot situated close to the Swedish border was established in a 90-year-old pine forest on sandy soil covered by lichens. The sample plot consisted of two subplots. They were both thinned but the slash from one subplot was transferred to the other which consequently received a double layer of tops and branches. In the course of time, several light thinnings were made in series. Here too the logging residue was transferred.

The results were analysed by Professor Alf Brantseg in 1962. The average annual volume growth during the 32 year observation period was 0.3 m^3sk* higher her hectare on the subplot with slash than on the subplot from which the slash had been removed. The difference corresponds to approximately 20 %. The greatest growth increase amounted to 1 m^3sk and occurred after 18 years. The growth was then approximately 3.5 m^3sk as compared to 2.5 m^3sk on the subplot without slash.

* m^3sk=Cubic metres of forest (volume of the entire stem above the stump, including bark).

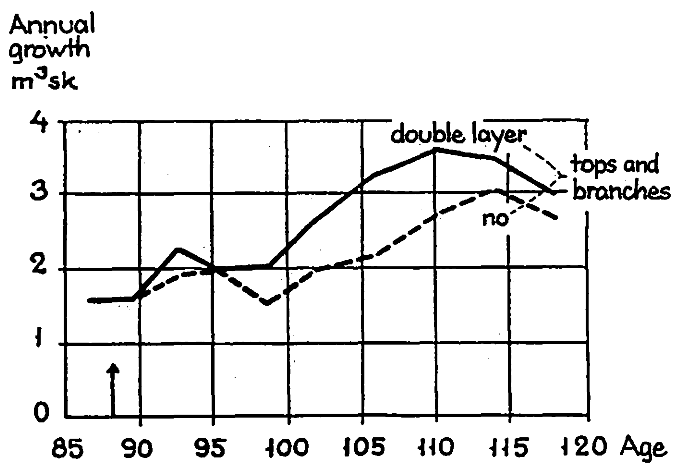

Figure 1.--Volume increment on plots with and without logging residue in the Norwegian experiment established in 1928. The arrow shows the year of first thinning.

The subplots varied slightly as to volumes before and after thinning and the trial contained no replications. Brantseg points out that the growth estimates are somewhat uncertain on account of some difference of site class between the subplots. However, he is still of the opinion that the results show that removal of logging residue in pine stands may cause a loss of increment amounting to approximately 10 %.

In order to study the effects of full-tree methods in young thinning stands, the author (Professor Andersson at the Swedish college of forestry) established a thinning experiment in western Dalecarlia in 1964. The subject was a 42-year-old sowed pine stand (Pinus Sylvestris), cleaned 11 years ago, and ready for a first commercial thinning. The number of stems were 1750 per hectare and the volume was 170 m^3sk. It is located on a mesic blueberry shrub vegetation site and the soil is rather fertile.

The experiment included 3 blocks, each containing 3 different treatments or plots. During the thinnings, pulpwood was logged in the ordinary way and from one plot in each block, branches and tops were removed and spread out on another plot as in the Norwegian experiment. Moreover, there is one plot in each block on which slash has neither been removed nor added to as in normal logging operations. The volumes felled in the thinning averaged 52 m^3sk/ha. The three plots within each block were thinned to the same basal area so that no such differences would influence the growth. At a second thinning, 10 years later, the removal amounted to 45 m^3sk/ha. The logging residue was handled in the same way as before.

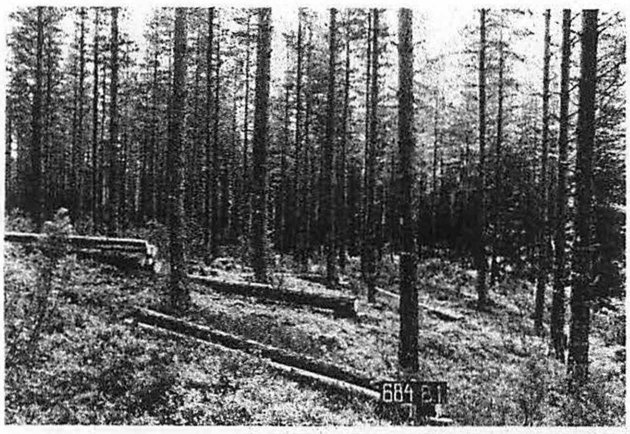

Figure 2.--The mentioned sowing of pine in Dalecarlia at 52 years of age, immediately after the second thinning. The logging residue was removed after both thinnings.

Pulpwood, 3 m in length and with a 7-cm (o.b.) minimum top diameter was cut in the first thinning. On one of the plots the tops and the living branches left as slash were weighed. The volume of the pulpwood was 52 m^3 (o.b.). The residual tops amounted to 9 m^3/ha, green weight 8.1 tons. The living branches, needles included, weighed 6.3 t after drying. The total dry weight of tops and living branches is estimated to be something like 10 t/ha.

In the second thinning pulpwood was cut to a minimum top diameter of 5 cm (o.b.). The volume of the pulpwood this time was 44 m^3 (o.b.) and the volume of the remaining tops 2.3 m^3 (o.b.). The dry weight of both tops and living branches totaled approximately 4 t/ha. The entire dry weight of logging residue of this kind from the two thinnings then amounted to 14 t/ha.

YIELD 10 % HIGHER

Measurements after 5 years showed that the stemwood growth on all the blocks had been higher on the plots where a normal amount of slash remained than where it had been removed. The same applied to the following 5 year period and also to the whole 16-year period up to the latest measurements which were made in 1980.

During these 16 years the yield per hectare has been 12 m^3sk higher where branches and tops were left. This corresponds to an approximately 10 % higher production. Where there was a doubled cover of slash, the growth had also been higher, but here the results vary more.

In 1964 a similar experiment was started by Professor C.O. Tamm in an 80-year-old pine stand of low density at Gällivare (northern Sweden). The growth after thinning was low because of poor site quality and a low standing volume, but during a period of 17 years the plots with slash remaining have shown a higher percentage of growth here also. The difference was 7 per cent.

Figure 3.--From the experiment in north Sweden. On this plot a double cover of slash was left at the thinning 17 years earlier.

GROWTH LOSSES ALSO ON FERTILE SOILS

A series of experiments, dedicated to the same problem, was established by the Department of Forest Research in Norway in 1972 - four of them in pine stands and four in spruce stands (Norway spruce). According to Björn Tweite, leader of these experiments, the trend is the same here as in Sweden. So far it is most obvious in the spruce stands.

The four Norwegian thinning experiments in spruce stands are established on good sites. The growth losses amount to 1.5 m^3/hectare, which corresponds to 11 %. This difference is strongly significant.

Many foresters believe it is a small risk of yield loss in harvesting full trees on good sites. Obviously it is not so.

AMOUNTS OF NUTRIENTS IN SLASH FROM THINNINGS

The slash from these Norwegian experiments in spruce stands contained on an average 113 kg of nitrogen, 108 kg of calcium, 14 kg of phosphorus and 57 kg of potassium. The slash from the youngest stand contained as much as 147 kg of nitrogen which, in Sweden, is an ordinary quantity when fertilizing in practice.

This problem has been investigated in Finland also. Mälkönen has examined the amount of nutrients lost during the first thinnings if the slash, including needles, is also removed. He has the average figures from 8 experiment plots in pine forests on a whortleberry vegetation site where the removal was 62 m^3 stemwood/ha. The residue of tops and branches was the equivalent of 8 t of dry weight. It contained an average of 26 kg of nitrogen, 3 kg of phosphorus, 14 kg of potassium and 16 kg of calcium. In spruce stands he has made similar studies on a more fertile site with blueberry shrubs and wood sorrel. Here the volume logged by thinning was 93 m^3sk/ha. The residue equalled 17 t of dry matter, containing 74 kg of nitrogen, 9 kg of phosphorus, 25 kg of potassium and 82 kg of calcium. This shows that considerable amounts of the nutrient are removed with the logging residue.

Research on biomass and the nutrient content of the different parts of the tree has been carried out in Sweden. In thinning stands, between 29 and 100 years of age, Albrektson has found that branches and needles together contained nitrogen amounting to 79-109 kg/ha.

COMMERCIAL FERTILIZER IS INFERIOR

There have been discussions as to whether or not the losses of nutrients may be compensated for by fertilizing. According to several ecologists the nutrition found in the logging residue is of considerably higher value than in the corresponding amount of fertilizer. The residue promotes the activities of the soil organisms as well. Furthermore, the shading by the slash may have a favourable effect on the moisture content of the soil which is valuable especially on dry soils. In forestry it is agreed that the traditional logging residue should be left on such soils.

A new series of experiments has now been started in thinning stands where the effect of utilizing full trees is being studied. The project includes fertilizing in connection with such logging. In late cleanings too it is possible to extract considerable amounts of biomass. Experiments in cleaning stands where the felled trees are left on the ground or removed, respectively, are still too few but new ones were carried out during the summer of 1983.

Summing up, I have to admit that there is, unfortunately, too few experiments that can explain the long-term effects of utilizing full trees in cleanings and thinnings. The tendency is, however, rather obvious in the case of thinnings. There definitely seems to be a loss of growth if the traditional logging residue is not left on the forest floor.

Literature cited

Albrektson, Arne. 1980. Relations between tree biomass fractions and conventional silvicultural methods. Ecol Bull. 32:315-327.

Andersson, Sven-Olof. 1983. Helträdsutnyttjande vid gallring och dess effekt på trädens tillväxt. Skogsfakta Supplement nr 1, 1983 pp 18-23. - Sveriges lantbruksuniversitet, skogsvetenskapliga fakulteten.

Brantseg, Alf. 1962. Irrigation and twigcovering experiments in Scots Pine forests. - Communicationes Instituti Forestalis Fenniae 55.7 Helsinki.

Mälkönen, Eino. 1976. Effect of whole-tree harvesting on soil fertility. - Silva Fennica vol 10. Nr 3.

Mälkönen, Eino. Biomass and nutrient removal in whole-tree harvesting in some coniferous stands thinned for the first time - Stencil.

IMPACTS OF WOOD HARVESTING ON STAND ESTABLISHMENT IN THE WESTERN EUROPEAN SCENE [1]

W. Heij [2]

ABSTRACT

A survey is given of the harvesting and the stand establishment methods, which are in use in Western Europe. There are many impacts from harvesting on stand establishment but not very many exact figures are known. The author is making a plea for a system analysis of the whole system of harvesting and regeneration, i.e. of the chain of activities from the mature stand up to the growing young stand. Except of a comparison of costs a study should be made concerning the decision making with respect to the choice of methods.

INTRODUCTION

Foresters in Western Europe are thinking in terms of stands which are generated in some way, tended and thinned during many years and finally harvested. By then we start a new cycle again. Trying to plan the management and the operations during the rotation of the stand, has an impact on the generation of the stand and forest, on the spacing of the trees, on the spacing of the roads, etc. For example forests in the Netherlands have been planted in a time that horse traction was still very important and the result is there are nowadays too many roads per ha, moreover of low quality. Especially, if the period between afforestation or reforestation and harvesting is large, it is difficult to plan so far ahead, since the labour circumstances, the methods and the equipment are changing. To be more specific, we can not oversee such a large period.

Harvesting and reforestation - in that following order - are much closer. It must be possible to have a young growing stand within a four years or even shorter period and this period can be overseen. There is, of course, an impact of stand establishment on tending, thinning and harvesting of the stand, but to make the situation less complicated it is not considered in this article.

In the present experience both operations, harvesting and stand establishment, are disconnected. Very often the operations are arried out by different people and no coordination takes place; this is even the case within a group of operations, for example between felling and skidding. The logger is interested in how to harvest the timber in the most efficient way without looking forward to the next stage. There after the planter has to find his way through a mess of logging waste to generate a growing stand within the shortest time possible and as cheap as possible. Decisions made concerning harvesting, have an impact on stand establishment. For example, what the reason may be, if large stumps are left behind on a clear cut, it is much more difficult, or even impossible to mulch the logging slash and to use planting machines.

It would be interesting to integrate both operations much more, and to consider both operations as a whole system. System analyses have been carried out till now concerning sub-systems, or even sub-subsystems. It gives a good comparison between the systems, but it does not say anything about the decision-making behind choosing the specific system if the preceding stage is not included.

System analysis of the whole system may lead to a better insight how the different operations are linked together and may lead to development of integrated machines which carry out logging and stand establishment at once. This, of course, lays in a far future and it will often not be possible because of climatic conditions in areas where the planting period is very short.

HARVESTING

The several operations, as felling, delimbing, debarking, croscutting, transport in the stand to the road, have still to be carried out, does not matter what kind of system and what kind of mechanization grade you choose.

Debarking is mainly mechanized. Mobile debarking machines are still in use, although more and more timber is debarked at the delivery

[1] Paper presented at the conference COFE/IUFRO - 1984. Orono, Maine, USA/Fredericton, New Brunswick, Canada. 12-18 August.

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point. This may be a central conversion site or the wood processing industry.

The full tree system, where the felling and the skidding are the only operations in the forest, is in Western Europe in use on a small scale. At the central conversion site you need the possibility to use the waste for energy or to get rid of it in an other way. Trials in the Netherlands to use the full tree system, to chip the trees totally and to produce green chips for the particle board industry were not very successful and the system has been abandoned.

The shortwood system and the tree length system - in the later case crosscutting can be carried out at the forest road or at a central conversion site - are in use mainly. On a small scale thinnings are harvested by means of processors, machines which are developed especially for this purpose. Smaller forwarders, more adapted to the circumstances, have been constructed. Forwarding of shortwood is often carried out by heavier farming tractors with crane in combination with a trailor; the investment for such a combination is far lower than for a specialized forwarder and the basic machine, the tractor, can be used for other purposes. For skidding tree lengths heavier farming tractors equiped with a graple are available.

The larger part of the felling and delimbing is still carried out with the power saw. Although the power saw has been improved over the years - less noise, less vibration, lighter weight - working with it is still heavy labour. Out of a viewpoint of ergonomics and safety, it remains a doubtfull tool. Although the in Scandinavia developed systems of felling and delimbing by means of the power-saw are ergonomically better working methods, workers have to learn to use the system and to adapt theirself to it. At the other side more untrained labour is moving in the forest, since employing own people is expensive and more timber is sold to a contractor.

The power-saw will not disappear very soon, since the more mechanized systems have their limitations, especially in a forestry you find in Western Europe. Because of the high population pressure on the forest one is looking for more "natural" harvesting systems, which results in smaller harvested areas and, if possible, in the use of natural regeneration.

The main objection against the use of machines in the forest is soil compaction and damage to the remaining trees. In this view and also in the view of wishing to propagate more "natural" systems, the use of horses for skidding is getting more popular. Sometimes you get the impression that the limitations for the use of a horse are forgotten. A horse can be very useful for concentrating trees, if the skidding distance is limited to an average of 25 m. Then, the bunches can be skidded to the forest road by adapted heavier farming tractors equiped with a graple. One has to keep in mind that horses, skidding tree lengths, also damage remaining trees. Moreover, horses, travelling along the same path several times, may cause a higher soil compaction than a tractor. In our department at the Agricultural University at the moment a study is carried out to get more insight in compaction of forest soils.

Western European forestry has always been more small-scale forestry than the forestry in Scandinavia and North-America. The in both areas developed forest machines are often of a size, which can not be used in Western Europe. Trials and careful introduction of these machines were not always successful. The progress of mechanization has been slower and is slowing down lately. At the other side, as from the middle of the seventies smaller forest machines and also equipment which can be used in combination with heavier farming tractors, have been developed, which are more adapted to local circumstances.

STAND ESTABLISHMENT

Stand establishment is executed mainly artificially, by planting or by seeding. Seeding can be used if seeds are available abundantly, which is not often the case, especially if you take provenance and quality of the mother stand into consideration. The by far larger part of the artificial regeneration is carried out by planting and in most cases bare-rooted plants are used. The planting stock at the nursery is selected and the larger, mainly twice transplanted plants are used for reforestation. Larger plants are used in combination with wider spacing. Larger plants will overgrow the weeds quicker and the crowns of the trees will come into closure earlier. The very wide spacing, especially of Pinus silvestris, which was applied in the Netherlands in the seventies, has been turned slightly backwards, since branching of the trees was very heavy.

If site preparation, i.e. manipulation of the site cover, can be omitted, depends on the amount of slash and undergrow and on the method of soil preparation and artificial regeneration which will be applied. The slash can be windrowed and eventually be burned. Reduction of slash and undergrow by means of mulching is often applied, especially in the Netherlands. An other applied method of reduction of slash is the use of a rolling chopper.

Soil preparation is mainly applied on spots, or on strips. In the Netherlands soil preparation is minimized. The carefully built up humus should not be disturbed by heavy soil preparation because of increased break-down of the humus and, consequently, loss of moisture and nutrients. This applies especially to the poorer sandy soils, where you can find most of the forests in the Netherlands. In Northern Germany, in more or less comparable circumstances, very often the stumps are removed from the area, windrowed together with the slash and the whole area is ploughed. It may be that the forest soils in Northern Germany are of a better quality than in the Netherlands, but there are also other objectives, as reduction of weed competition and late frost damage, and the use of cheaper one-year old plants.

Operational analysis of systems for artificial regeneration shows that systems without mechanization or partly mechanized systems prevail in Western Europe, although fully mechanized systems, as for example the forest-plough-planting machine, are cheaper. Use of the forest-plough-planting machine, also in combination with windrowing the logging slash, a reasonably cheap method; is in the Netherlands limited to private forest owners, while others use more expensive methods. The use of the mulching machine for site cover manipulation became very popular in the Netherlands in the seventies, but it is a costly method, especially if it is followed by mechanized spot-wise soil preparation and handplanting. Use of more expensive methods can only be explained, if the results on the long term will be better.

At the end of the seventies a Danish planting machine has been introduced, a machine, which is combining site preparation, soil preparation and planting in one machine. Prelimenary research showed that the costs of establishment by means of this machine are at a level of the costs of the cheapest methods. The machine can be used in easy and average circumstances.

In view of the more ecological methods natural regeneration is propagated. This can be done according to the selection felling system of single trees or of small groups. Of course, the quality and the provenance of the stand has to be such, that it is meaningful to make use of natural regeneration. It might be a cheap establishing method, but the costs of tending and thinning the stand will be higher than in the case of clearcutting larger areas followed by artificial establishment of a limited amount of plants. The possibility of using mechanized systems will be limited and it is an open question how much damage will be done to the remaining stand. It is often argued that natural regeneration will improve the stability of the stand. This will only be true if the stands are tended properly and if the trees get enough room for development. In Germany, and especially in Southern Germany the system is in use already a long time, although only 10% of the total reforested area in Western Germany is treated according this system.

IMPACTS

System analyses give a good comparison of costs of different systems, but it is often not clear why different systems are used in apparently similar circumstances. System analyses have been carried out on subsystems but never on the overall system of harvesting and stand establishment.

It is clear, there is an impact of harvesting on stand establishment. The way a logger leaves the logging area behind, may exclude special stand establishment methods or may include extra work to make a special method possible. Twenty years ago in the Netherlands final felling, especially of Pinus silvestris was executed harring-bone-wise; the branches could be windrowes easily by hand and a clean logging area was left. Nowadays parallel felling takes place and the logging waste is left scattered over the area. At one side this depends on the used logging machines, at the other side this depends on the fact, that more untrained labour is moving into the forest.

Apparently establishing methods are used, which are too expensive considering the circumstances (table 1). The reason may be the equipment for a cheaper method is not available and the available more expensive system is used. Or it may be possible one is equiped for the worst circumstances and the equipment is used in all circumstances.

I am pleading here for making a system analysis of the total chain of activities from the mature stand up to the growing young stand (fig. 1). This will give a better insight in the whole system and perhaps will lead to a better coordination of activities.

Forestry in Western Europe is tending to a

Site preparation	Soil preparation	Planting	% Afforested area private	% Afforested area state	Relative costs per ha
windrowing, manual	-	manual	15	6	100
-	-	manual	7	11	108
mulching	-	manual	7	6	167
mulching	forest plough	manual	43	20	172
mulching	spotlike scarifier	manual	-	18	172
mulching	forest plough planting machine		17	8	176
mulching	plant hole grubber	manual	11	31	206
Total area (ha)			154	140	

Table 1. — Some of the used establishment systems and relative costs in the private and state sector of forestry in the Netherlands (1979)

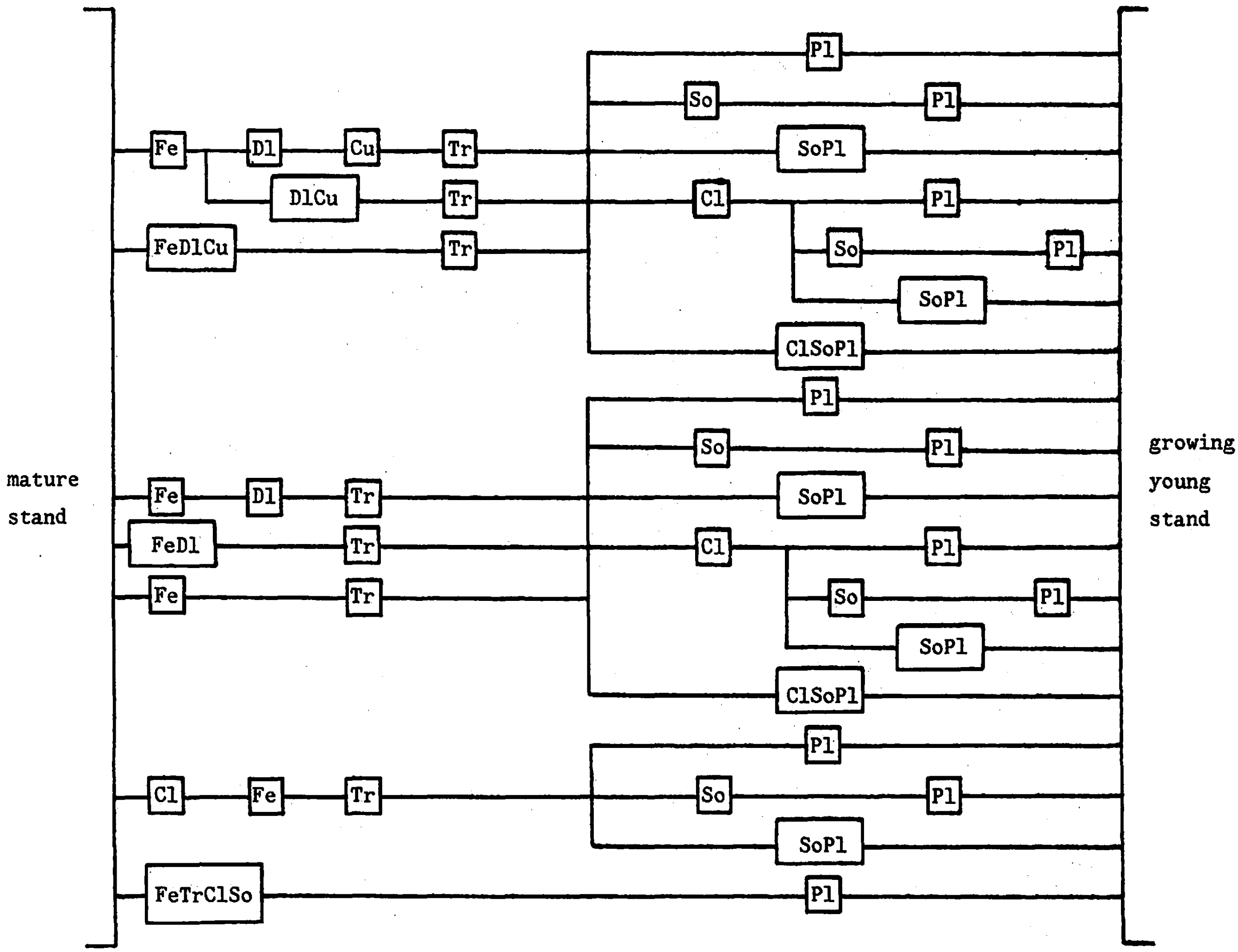

Figure 1. -- Possible systems in a whole system of harvesting and stand establishment in the Netherlands.

☐ = (sub)system; an integrated system, if more codes are brought together in one block.

Fe=felling Cu=crosscutting Cl=clearing/site preparation
Dl=delimbing Tr=terraintransport So=soil preparation
Pl=planting

stronger application of ecological considerations. In the case of clear cut and artificial regeneration this means decrease of the size of the object area, for example < 1 ha. The final consequence may be the system of selection felling of single trees or very small groups of trees; in that case you might make use of natural regeneration. Contrary to this, an Eastern German study shows that biologically and technically the best results are reached, if the size of the object areas varies between 3 and 10 ha.

Decrease of the size of the object area implies increase of costs. Decrease of the size of the object area means moving people and machines more often. This will increase the amount of general times, decrease productivity and increase costs. Moreover the productivity of a machine at a smaller area will decrease, since more turns have to be made.

Use of the system of slection felling of groups or single trees will increase costs or decrease yields, since:

- harvesting without damage to the remaining stand has to be carried out more carefully. Costs of harvesting a shelter above a young stand, a silvicultural system, which is often applied in areas where late frosts are occuring, may be indicative.
- in many cases the use of natural regeneration will not be possible, because the quality of the stand is too low. Artificial regeneration will be necessary. The smaller the size of the object area, the higher the costs will be.
- economical and technical limitations necessitate more traditional forest labour. Activities can

not be executed by machines, but have to be carried out manually. Moreover, using traditional methods will have impacts on ergonomics and safety.
- supervision has to be intenser,
- if the same amount of timber will be harvested per ha per year, timber felling will take place more scattered over the forest area. Transport of the timber will be more expensive.

FINAL REMARKS AND RECOMMENDATIONS

Forestry in Western Europe has manifold objectives, as protection against wind and water erosion, satisfaction of the psycho-social needs of mankind and wood production. A high pressure of the population which considers the forests as public owned, has an influence on the way of managing the forests. Moreover, the forests are owned by many owners; the average size of the woodlot is small.

In general you can speak of small scale forestry. This means there are limitations concerning the possibility for mechanization and the level of mechanization. Mechanization is not an aim in itself; except of a higher productivity, one of the objectives is humanizing hard forest labour.

Anyhow, if wood production is still one of our objectives, the forests will be harvested and new stands have to be established. From the mature stand up to the growing young stand a chain of activities has to be carried out. These activities we want to carry out as efficient as possible. At the moment the motivations of decisions concerning the choice of methods for the different activities are sometimes very cloudy. Used subsystems vary in costs sometimes twice.

In view of this I would like to recommend the following:

- A system analysis should be made of the whole system of harvesting and stand establishment, not only as a comparison of costs, but also to get more insight in process of decision making concerning the different steps in the chain of activities.
- Further development of methods, tools and equipment which are adapted to small scale forestry and also of methods and tools for mechanical weed control in the first stage of the establishment, since the use of chemicals has been or will be limited because of public pressure.

LITERATURE

Anon. 1979. Kostensenkung bei Holzernte und -transport. Allg. Forst Zeitschrift 24 (51/52), pp. 1430-1432.

Bäckström, P.O. 1981. Site preparation and direct seeding in Swedish Forestry. Proceedings Symposium Forest Regeneration ASAE, Raleigh (NC), U.S.A., pp. 208-216.

Bol, M. 1976. The role of mechanization in small scale forestry. Proceedings Joint IUFRO/ FAO Meeting, XVI World Congres, Norway, pp. 48-64.

Bol, M., Brand, R. en W. Heij. 1981. Bosbouw: schaal en kosten. Nederlands Bosbouw Tijdschrift 53 (3), pp. 100-109.

Braches, P. and A.C. Schlaghamersky. 1979. Beurteilung der Verfahren zur Schlagabraumbeseitigung nach Leistung, Kosten und die Auswirkungen auf dem nachfolgenden Bestand. Allg. Forst Zeitschrift 34 (37), pp. 991-993.

Brunig, E.F. 1979. The means to excellence through control of growing stock. Weyerhauser Science Symposium Forest Plantations, Tacoma, U.S.A., pp. 201-224.

Denniger, W. 1980. Erfahrungen mit der Forstplanzmaschine der Dänischen Heide Gesellschaft. Allg. Forst Zeitschrift 35 (15), pp. 407-410.

Heij, W. and N.A. Leek. 1981. Impacts of wood harvesting technology on soil and vegetation. Proceedings Interdivisional XVII IUFRO World Congres, Japan, pp. 21-32.

Höfle, H.H. 1981. Mechanized operations in forest regeneration in Western Germany. Proceedings Symposium Forest Regeneration ASAE, Raleigh (N.C.), U.S.A., pp. 152-156.

Leek, N.A., Tissing, A. and J.L. Volmuller. 1978. Boswerk in Nederlands. Nederlands Bosbouw Tijdschrift 50 (9), pp. 272-284.

Leek, N.A. 1980. Bosverjonging in Nederland. Nederlands Bosbouw Tijdschrift 52 (1), pp. 6-16.

Leek, N.A. 1980. Ervaringen met de plantmachine van de Deense Heide Maatschappij. Rapport nr. 232, Rijksinstituut voor onderzoek in de bos- en landschapsbouw "De Dorschkamp", Wageningen, Nederland.

Leibundgut, H. 1984. Natürliche Verjüngung - Spielerei oder Wirtschaftliche Notwendigheit. Allg. Forst Zeitung 90 (2), pp. 28-31.

Mrazek, F. 1979. Der Einfluss der Flächengrösse auf Sicherung und Qualität fünfjähriger Kiefernkulturen. Soc. Forst Wirtschaft 29 (4), pp. 111.

ROLL SPLITTING AS AN ALTERNATIVE TO CHIPPING FOR A WOODY BIOMASS FUELS PREPARATION[1]

Dennis T. Curtin[2]

Abstract--A prototype roll splitter, developed by K. C. Jones and Associates for Forest Engineering Research Institute of Canada (FERIC), is being cooperatively tested by FERIC and TVA. The objectives of the test are to document the energy required to fracture round bolts of a variety of hardwood species and determine the effects of the fracturing process on moisture content and drying characteristics of the fractured bolts.

Energy consumption, dewatering, and drying rates are presented.

[1]Paper presented at the conference COFE/IUFRO - 1984. Orono, Maine, USA, 12-14 August.

[2]Dennis T. Curtin is Timber Harvesting Operations Project Manager in the Division of Land and Economic Resources, Tennessee Valley Authority (TVA), Norris, Tennessee, USA.

THE SPRUCE BUDWORM IN MAINE[1]

David E. Fosbroke, Douglas R. Gill, and Thomas J. Corcoran[2]

ABSTRACT

The current spruce budworm epidemic is the most widespread of this century, affecting more than half of Maine's 8 million acre spruce-fir forest. The economic importance of this timber resource, particularly for pulp and paper products, stirred early interest in the monitoring of spruce budworm population levels.

Forest stands containing high percentages of balsam fir are very susceptible to severe defoliation, which results in growth reductions and eventually mortality. During severe budworm infestations, widespread mortality occurs in mixedwood stands as well as spruce-fir stands. In addition to growth loss and mortality, spruce budworm defoliation can cause major problems; one problem involves how to best salvage potentially high volumes of timber before it deteriorates beyond usable limits. This problem is not easily solved because decay, windbreak, and blowdown of budworm damaged trees result in the waste of this usable resource if salvage operations are not completed within one to three years after tree mortality.

The most common and effective method of spruce budworm control is the aerial application of chemical and biological insecticides. Silvicultural control methods focus on the removal of balsam fir from susceptible stands as a means of reducing the risk of budworm predation. The combination of insecticide use, silvicultural practices, and insect monitoring, commonly referred to as integrated pest management, provides a comprehensive method of moderating future budworm population surges.

Regardless of the magnitude of insecticide use or silvicultural prescription, current budworm caused mortality will continue for some time, even after depleted food supplies have reduced budworm populations to endemic levels. However, with the development of sound economic strategies for planning optimal salvage schemes and control levels, we can reduce the magnitude of potential timber losses due to budworm devastation.

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[1]Poster presented at the conference COFE/IUFRO - 1984. Orono, Maine, USA, 12-14 August.

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MECHANIZED SHORTWOOD THINNING SYSTEM[1]

ABSTRACT

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First commercial selective thinning in southern pine plantations is feasible when using small machines to produce shortwood. The primary advantage of selective thinning is that trees which will produce the most income in the future are left as opposed to row thinning which removes many of the high quality trees. Conversion of felled trees to shortwood before transporting out of the woods is an advantage in a selective thinning operation. The shortwood can be loaded on small forwarders and hauled out of the stand in narrow corridors which meander around quality trees normally removed for straight access routes needed for skidders.

A feasible operation consists of feller bunchers, chainsaws or mechanical processors for delimbing and bucking, and forwarders. Small, highly maneuverable rubber-tired feller bunchers are used to fell trees and bunch them at access corridors. The operators select which trees are to be removed. Narrow, winding corridors (3.5m) are opened about every 27m (90 ft). Trees are selectively cut between the corridors. In manual processing, bunches with approximately 15 trees each are laid parallel to the corridors. Chainsaw operators delimb and buck the trees in the bunches into shortwood. Because of the large bunches, no additional piling of the shortwood is required to optimize forwarder productivity.

An alternative to manual delimbing and bucking is mechanized processing. Processors are safer and require less labor. Trees are bunched perpendicular to the corridors by feller bunchers with 20-25 trees per bunch. The processor operates from the corridor with limbs and tops remaining to improve trafficability and reduce compaction. The processed shortwood is piled along the edge of the corridors.

Forwarders extract approximately 4 bunches per turn for the manual processing alternative or 2 piles per turn behind the mechanical processors. Forwarding distance averages 122m (400 ft) with maximum distances of about 275m (900 ft). With approximately 8 trees per cubic meter (28 trees per cord) the average volume per turn is $7.2m^3$ (2 cords). Wood is off-loaded onto set-out trailers at the landing.

For an average daily production of $21.5m^3$ (78 cords), the balanced systems would be as follows:

Machines	Chainsaw Processing	Mechanical Processing
	--- Number of Machines ---	
Feller bunchers	2	2
Chainsaws	5	-
Processors	-	2
Forwarders	3	3

This mechanized shortwood system with either chainsaw or mechanical processing has proven cost effective in thinning loblolly pine plantations between ages of 14-18 years old in southern USA. Current bolt length is 2.3m (7.5 ft). The result is an acceptable silvicultural treatment completely paid for by the value of the pulpwood removed.

[1]Poster presented at the conference COFE/IUFRO-1984. Orono, Maine, USA, August 12-14.

ROAD AND BRIDGE CONSTRUCTION[1]

A. Allen Murphy[2]

ABSTRACT

Introduction

The material on this poster was a combination of materials on road construction, culvert locations, setting pools, and basins, filter strips, horizontal and vertical road shoulder slopes, road locations in the field. Other supplemental material included bridge terminology, bridge plans, road classifications, culvert installation, information on skidder trails and other road information.

Description of Data Base

The data base of this poster is from company plans of bridges, field data collected over a period of years, and pages of the company manual on road and bridge construction. This material was supplemented by photos of work in the field.

Conclusions

The data put together for this poster is a summary of field data put down on paper in a plain and simple way by using plans and sketches to show the proper road construction in the field, proper bridge design, and culvert installation.

The only literature used was the Seven Islands Land Company booklet entitled "Access Road, Water Crossings and Skidder Trail Layout" by Murphy.

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[1]Poster presented at the conference COFE/ IUFRO - 1984. University of Maine, Orono, Maine, USA, 12-14 August, 1984.

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A MAP-BASED INFORMATION SYSTEM FOR LOGGING ROAD MANAGEMENT[1]

Maarten A. Nieuwenhuis and Thomas J. Corcoran[2]

ABSTRACT

The use of computerized information systems in forest management is increasing rapidly. Most of these systems are developed primarily for stand management. An important section of forest management which is often not included is the transportation and road construction aspect.

In the last decade more emphasis has been directed towards this part of the overall managing process. Three reasons warrant inclusion of road construction, road maintenance and transportation scheduling in the information system: the increase in construction and fuel costs, the growth of the existing road networks, and the increase in road construction due to the salvage operations of spruce budworm damaged timber in the Northeast of the United States and Eastern Canada.

A computerized map-based information system, which combines the easy accessibility of maps with the data storage and retrieval capabilities of a computerized data-base, provides the management with a tool to deal with the large amounts of data involved. The output capabilities in the form of maps and/or reports make the system flexible enough to suit the needs of different users.

The road network management capabilities of the system are enormous: road and structure maintenance scheduling, selection of road segments and structures for upgrading procedures, traveltime estimations, shortest route determinations, and possibly the selection of an optimal manner, using soil; river, stream, lake; covertype; and elevation data from the total system.

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[1]Poster presented at the conference COFE/IUFRO - 1984. Orono, Maine, USA, 12-14 August.

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PENDULUM BALLOON LOGGING SYSTEM [1]

Eldon D. Olsen[2]

Abstract--We tested the concept of using a tethered balloon for load transport. Potential system applications are ship to shore transport, logging, and heavy construction in remote areas. System capabilities were predicted using computer models and small scale field experiments. The system is still in a developmental stage.

SYSTEM DESCRIPTION

The pendulum-swing system differs from conventional balloon systems with the load always suspended directly beneath. In this new system, lift for the load is provided by a stationary balloon and the load is swung to the landing in a pendulum-like movement.

An application of the pendulum-swing balloon system is illustrated in Figure 1. Components include a natural-shaped balloon with a capacity of 31,000 m^3, three or more guylines, and a conventional yarder.

The helium-filled balloon is held in a relatively fixed position 450 m above the ground by means of three or more guylines, at least one of which is attached to a winch capable of spooling the entire length of the guyline. This winch allows the balloon to be repositioned by changing guyline length. The remaining guylines are anchored near the perimeter of the harvesting unit.

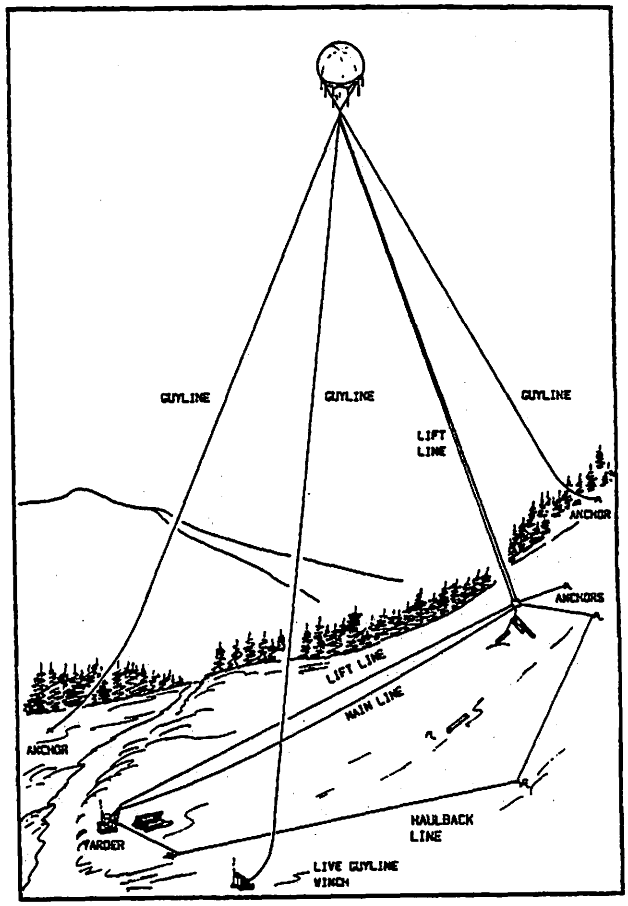

Figure 1.--Pendulum swing balloon logging systems.

RESULTS

Because the length of three separate lines (mainline, haulback, lift) are simultaneously changed the system will be computer controlled. Field tests of models have indicated that the system is relatively stable under normal operating conditions. Stability comes from the guylines restricting balloon movement and from operating lines controlling the load hook position.

The major restriction of this system is its vulnerability to high gusty winds. For winds in excess of 46 km/hr (25 knots) the system must be secured in a sheltered location. The initial cost of the system is about $2,688,000 (U.S.). Operating costs are about $900/hr based on an 184 working day season and an 8 person crew or 10% more than the hourly operating costs of conventional balloon systems. A typical load/ unload cycle can be accomplished every 5-6 minutes. Predicted productivity comparisons indicate that the pendulum system is superior to conventional balloon logging (Yo-Yo system) only at yarding distances under 800 m (fig 2). The comparison is for Pacific Northwest U.S.A. conditions with 100 metric tons per hectare to be harvested.

Funding for the project was provided from a grant to the OSU Foundation by J.L. Bell who holds a 1974 U.S. Patent Number 3807577 on the pendulum swing concept.

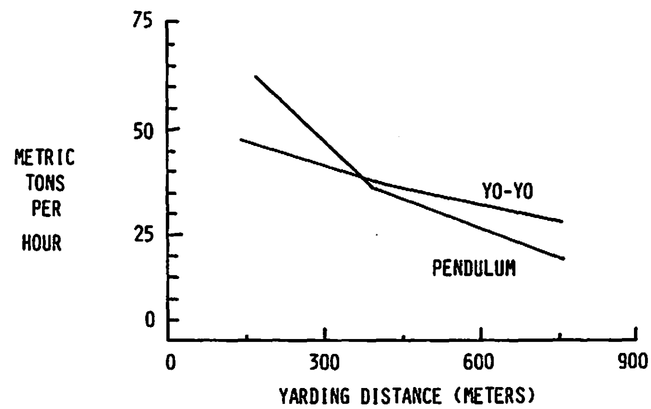

Figure 2.--Comparison of production.

[1]Poster presented at the conference COFE/IUFRO 1984. Orono, Maine, USA, 12-14 August.

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MICROCOMPUTER-BASED FOREST OPERATION PLANNING DECISION SUPPORT SYSTEMS[1]

E.W. (Ted) Robak[2]

Abstract.- North American forest operations are generally highly mechanized and capital-intensive and are, therefore, highly sensitive to planning deficiencies. A study of contemporary operational planning methods has revealed that, although the basic analytical techniques employed are usually adequate, the process itself is not conducive to the application of sensitivity analysis. Managers have indicated that they are not being given the information, tools and/or time to formulate better operating plans or to change those plans in reaction to unforseen problems or opportunities. A decision support system (DSS) could reduce these shortcomings in the management decision-making process by combining effective data-base management, modeling and dialog capabilities to provide decision support for unstructured and semi-structured problems. Proper application of the DSS concept could greatly enhance the abilities of managers to plan and control forest exploitation activities.

The goals of a DSS for forest operational planning and control should be to improve a manager's ability to analyze the potential effects of future operating decisions and accurately estimate the efficiency of ongoing harvesting, transportation, stand establishment and support activities. Such a support system should be capable of retrieving information from forest resource, equipment and financial data-bases, it should be able to effectively interact with the strategic decision-making environment and yet must always be accessible to a manager in his workplace, no matter how remote that might be. One microcomputer-based DSS currently under development (OP-PLAN) will use the entire operating budget as the major objective decision criterion for sensitivity analysis, while relying on a manager's experience and intuition to ensure that physical, biological and organizational constraints are properly recognized. OP-PLAN would also be used as a managerial control tool during the operating year by facilitating the formulation of plan revisions and new budget estimates for comparison against the original budget. However, it should be recognized that although this DSS could help managers improve their operational planning and control, its utility will be greatly increased when it forms part of a network of specific DSSs that are integrated vertically and horizontally (connecting all levels and departments of an organization) and that effectively access the rich information environment in which they exist.

[1]Poster presented at the conference COFE/IUFRO - 1984. Orono, Maine, U.S.A, 12-14 August.

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ABSTRACT

THE EFFECT OF HEAT STRESS ON FOREST HARVESTING PRODUCTIVITY[1]

Leo A. Smith, Michael R. Seay, and Donald L. Sirois[2]

INTRODUCTION

The effect of heat stress on the productivity of forest harvesting personnel has been considered by only a few investigators. Both Axelson (1974) and Smith (1984) present speculation on the topic, but actual forest harvesting data supporting the observations are not presented. The present poster summarizes the effects of heat stress on productivity revealed by analysis of production records of three harvesting crews working in southeastern Alabama.

DESCRIPTION OF THE DATA BASE

Daily production records from two years of operations of three six-man logging crews employed by a large harvesting company in southeastern Alabama were selected for study. During the study period each crew experienced no turnover in personnel, harvested similar stands utilizing similar equipment and methods, and operated under relatively stable market conditions. Crews 1 and 2 typically worked on dry, upland terrain and their data were combined for analysis. Crew 3 typically was assigned work in low lying areas. The harvesting system consisted of chainsaw felling, delimbing and topping, cable skidding, and loading of whole stems. Crew 3 differed in that track rather than tire mounted skidders were typically utilized. Natural stands of mature pine were harvested; some stands had been prelogged for pulpwood. Environmental data were readings recorded every three hours by the nearest (80 km) station of the U.S. National Weather Service. A total of 806 crew/days were included in the final data set after elimination of days involving atypical harvesting activity.

ANALYSIS AND RESULTS

A number of heat stress indexes have been proposed to reflect the composite effects of the different variables in the occupational thermal envoironment. The Oxford Index was used in this study. The Oxford Index (WD) is defined as (.85*wbt + .15*dbt) The WD was calculated using the average of the temperature readings from the 0900, 1200, and 1500 hours of the day.

The relationships between harvested weight per manhour and the following independent variables were evaluated: WD, week day, and tract rating. The tract rating was a numerical score assigned by the logging company reflecting the relative desirability of a tract. Analysis of variance indicated that production was significantly affected (.10 level) by tract rating and WD for crews 1 and 2. Only tract rating was significant for crew 3. Attempts to develop regression models of production per manhour as a function of tract rating and WD resulted in very low R-square values.

Based on the results of Duncan's multiple range test the crew 1 and 2 tract ratings were divided into a high and low group. Similarly, the WD values were divided into a high group (WD>.25 degrees C) and a low group (WD <=25). The combination of high track rating and low WD resulted in 15.8% greater average productivity than the low track rating-high WD combination. There was no interaction between the grouped variables and the two middle groups differed by only 2.8%.

CONCLUSION

The analyzed data indicated a reduction in productivity under WD conditions greater than 25 degrees C. A model describing productivity reduction as a function of WD could not be developed most likely due to the inherent daily variability in harvesting data.

LITERATURE CITED

Axelson, O, 1974. Heat stress in forest work. 31p. Food and Agricultural Organizational of the U.N., Rome.

Smith, L. A, 1984. Observations on the effect of heat stress on forest harvesting personnel. Proceedings of the 1984 international conference on occupational ergonomics. (Toronto, Ontario, May, 1984): 126-129.

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[1]Poster presented at the conference COFE/IUFRO - 1984. Orono, Maine, USA, 12-14 August.

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RESIDUAL HARVESTING SYSTEMS FOR THE SOUTH[1]

ABSTRACT

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More importance is being placed on the utilization of small diameter, unmerchantable trees as well as residuals remaining after harvest. This is partly due to the increasing uses for forest biomass and the increasing costs of fossil fuels. Another important reason is to offset the high cost involved in regeneration with intensive mechanical site preparation.

New techniques and machines are being developed to harvest more of the woody biomass for energy. Methods range from conventional harvesting systems with portable chippers to specialized machines and innovative concepts. Some research emphasis has been directed toward the development of multi-functional harvesting machines that fell the unmerchantable trees and/or pick up the residual slash for chipping and primary transport. Other concepts include baling and hogging the residuals behind conventional harvesting operations.

Recovering energy wood economically is a major problem due to the high cost of collecting, handling, and transporting the low volume trees and components. One solution is chipping the wood at the site and transporting to the mill boiler in vans. There are four separate concepts being developed for this purpose:

Portable Chippers - Chippers in this category are usually mounted on a trailer and are towed to the site and operated at the landing. They are an integral part of a conventional system that includes feller bunchers and skidders. Products may be only energy wood or a mixture of energy wood and merchantable roundwood using a loader. The nature of the system demands the harvest of whole trees to certain diameter limits. Recovery of the downed slash is infeasible. Therefore the energy wood is pre-harvested or simultaneously harvested with the other products from the stand.

Such a system offers the potential for increased utilization at competitive costs for certain stands. Current equipment can be used. Disadvantages include high costs associated with low volumes of biomass and non-recovery of logging slash.

Mobile Chipper Harvester - The concept is a chipper mounted on a carrier with felling capability for small trees and brush in a continuous swath. Chips are discharged onto a second vehicle for forwarding to the landing or other unloading point. With this process, the trees in otherwise unmerchantable stands can be utilized for energy wood. The system can be applied in post-harvesting operations to recover the remaining standing trees and logging slash on the site. The advantage is the utilization of biomass that would otherwise be wasted. Use of this system could result in more cut-over acres being reconverted into merchantable stands. The product will be cleaner because the material is not skidded. This is a specialized system with only one product capacity.

Mobile Chipper Harvester-Forwarder - This machine concept includes the addition of an onboard provision for collecting the chips and forwarding to the landing. Instead of having several machines, the system consists of one machine which performs all the functions of felling, chipping, and forwarding.

There are advantages in having less machines in the system. Disadvantages include restrictions to certain stands and productivity loss because of the forwarding function. Little or no downed biomass can be collected with this system.

Mobile Chipper-Forwarder - The concept is based on a self-loading chipper mounted on a carrier. Working behind a feller buncher, trees from piles are chipped in the stand and discharged into an onboard container. The chips are forwarded to the landing by the machine for dumping into an open-top van. Because feller buncher are a part of the system, tree diameter is very critical for economical recovery. The potential for recovering slash may be limited.

Since the skidding function is removed, then the system has the potential of producing cleaner chips. The separation of the felling function improves system utilization when one machine is down. There is a productivity loss because of forwarding with the same machine that does the chipping.

In summary, a practical approach to better utilization of the woody biomass for energy wood is to use conventional equipment for harvesting the small diameter trees to economical limits. For recovery of the residual slash, more specialized machines are being developed. They offer the potential of better utilization at an economical cost and a reduction in the site preparation needed for regeneration.

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