

NE-RWU-4154  
Problem Area 2  
1.21  
Available  
VM PR/WFWAK



# PROCEEDINGS

of the  
Society of American Foresters  
1999 National Convention  
Portland, Oregon  
September 11-15, 1999

Dwyer, John P. 1999. Logging impact on uneven-aged stands of the Missouri Ozark Forest Ecosystem Project. In: Proceedings Society of American Foresters 1999 national convention; 1999 September 11-15; Portland, OR. SAF Publ. 00-1. Bethesda, MD: Society of American Foresters: 210-222.

©2000  
Society of American Foresters  
5400 Grosvenor Lane  
Bethesda, MD 20814-2198  
[www.safnet.org](http://www.safnet.org)

SAF Publication 00-1  
ISBN 0-939970-81-3

# Contents

Page

Preface .....	iii
Remarks by the Governor of Oregon .....	1
<i>John Kitzhaber</i>	

## General Session I

### *Science and Practice of Forestry: A Historical Look*

Foresters Roles' as Forestry Changes .....	7
<i>Hal Salwasser</i>	
The Evolution of American Forest Policy: Two Appraisals. ....	9
<i>V. Alaric Sample</i>	
How Social Values Have Affected Forest Policy .....	16
<i>Jo Ellen Force and Greg Fizzell</i>	
The Influence of Science and Technological Change on Forest Management since 1900 .....	23
<i>Stephen P. Mealey</i>	

## General Session II

### *Science and Practice of Forestry: Contemporary Approaches*

Science and Practice of Forestry: Contemporary Approaches .....	37
<i>James E. Brown</i>	
Regional Landscape-Scale Planning—A Contemporary Approach .....	40
<i>Elaine Zielinski and Robert Williams</i>	
Managing Michigan's State Forests for Sustainability .....	49
<i>Jerry Thiede</i>	
Managing Weyerhaeuser Company Forests .....	58
<i>John P. McMahon</i>	
The Longleaf Alliance: A Regional Longleaf Pine Recovery Effort. ....	67
<i>Rhett Johnson and Dean Gjerstad</i>	

## General Session III

### *Science and Practice of Forestry: The Future...Coping with Uncertainty*

Living the Future: Perspective of a Mid-Career Professional .....	71
<i>Laura Falk McCarthy</i>	
Living the Future: The Perspective of an Early-Career Forester .....	75
<i>Tamara L. Cushing</i>	
Looking to the Future: The Vice-President's Perspective .....	77
<i>Frederick W. Ebel</i>	

## Working Group Technical Sessions

### A1

#### *Practical Approaches to Incorporating Auxiliary Information in Forest Inventory*

PPP Sampling for Total Volume with and without Prior Predictions .....	83
<i>Steen Magnussen</i>	
Precision versus Cost Relationships When Using Growth Models to Update Annual Forest Inventories .....	93
<i>Ronald E. McRoberts and Veronica C. Lessard</i>	
Extending Stand Exam Data with Most Similar Neighbor Inference .....	99
<i>Melinda Moeur</i>	
Graphical Methods for Uniform Prior Distributions in Bayes Estimation .....	108
<i>Richard G. Oderwald</i>	

#### *Key to SAF Working Groups*

A1	Inventory	C4	Range Ecology	E4	Management Science and Operations Research
A2	Remote Sensing and Photogrammetry	C5	Wildlife and Fish Ecology	E5	Technology Assessment and Future Analysis
A3	Biometrics	C6	Physiology	F1	Wilderness Management
A4	Geographic Information Systems	D1	Forest Genetics and Tree Improvement	F2	Recreation
B1	Nonindustrial Private Forestry	D2	Silviculture	F3	Education and Communication
B2	Urban and Community Forestry	D3	Forest Production and Utilization	F4	Human Resources
B3	International Forestry	D4	Fire	F5	Philosophy and History
B4	Agroforestry	D5	Forest Entomology and Pathology		
C1	Forest Ecology	E1	Economics, Policy, and Law		
C2	Soils	E2	Land Use Planning, Organization, and Management		
C3	Water Resources				

**A3, D1**

---

***Biometrics: Research and Application***

The Stand Visualization Model (SVM) for Fort A.P. Hill ..... 115  
*David L. Keys and Harold E. Burkhart*

Results of an Inventory of Spruce Bark Beetle Mortality, Kenai Peninsula,  
Alaska, 1997 and 1998 ..... 122  
*Vernon J. LaBau*

Growth Model for All-Aged Shortleaf Pine Stands ..... 130  
*Benedict Schulte, Joseph Buongiorno, and Kenneth Skog*

**B2**

---

***Global Implications of Local Urban Forestry Practices***

Impact of Urban Forest Management on Air Pollution and Greenhouse Gases ..... 143  
*David J. Nowak*

Current Stresses and Potential Vulnerabilities: Major Findings of the  
Gulf Coast Regional Climate Change Assessment Workshop ..... 149  
*Zhu Hua Ning and Kamran K. Abdollahi*

A National Assessment of the Urban Forest: An Overview ..... 157  
*John F. Dwyer and David J. Nowak*

Urban Forestry Professionals: Who Are We? ..... 163  
*Hope A. Bragg, Michael R. Kuhns, and Dale J. Blahna*

Quantifying the Economic Benefits of Urban Shade Trees Using a  
Geographic Information System ..... 164  
*Courtenay Park, Daniel Unger, Andrew Carver*

**A4, B3, B4, C1, C4, D2, D3, D5, E5, F1**

---

***Management and Marketing of Nontimber Forest Products: Lessons Learned from Overseas***

Analyzing Extraction of Nontimber Forest Products in Pintao, Venezuela ..... 169  
*Gabriela Silva and Marc E. McDill*

The Danish Christmas Tree Industry: Implications for the US in Production  
and Marketing of Real Trees ..... 175  
*Craig R. McKinley and L. John Frampton*

**A3, B4, C2, C6, D1, D2, D5**

---

**Perspectives and Prospects for the Use of Short-Rotation Woody Crops**

- Economic Analysis of Short-Rotation Tree Plantations: The Investor's Perspective . . . . . 242  
*Carolyn J. Henri*
- Environmental Aspects of Biomass Crop Production . . . . . 248  
*Virginia R. Tolbert, Wije Bandaranayake, Don Tyler, Allan Houston, David Mays,  
David E. Pettry, Frank C. Thornton, J. Dev Joslin, Bert R. Bock, S. Schoenholtz, T.H. Green*

**D2**

---

**Silviculture for the Millennium: Remembering Our Past, Creating Systems for Our Future**

- Application of Silvicultural Systems in Northern New England Forests . . . . . 255  
*Dale S. Solomon and William B. Leak*
- Integrating Hazard and Other Factors into Silvicultural Decisions to  
Achieve Landscape Objectives . . . . . 262  
*Pil Sun Park and Chadwick D. Oliver*

**D2**

---

**Silviculture for the Millennium: Remembering Our Past, Creating Processes for Our Future**

- The Effects of Partial Cutting on Stand Structure and Growth, and Forest Plant  
Communities of Western Hemlock Sitka Spruce Stands in Southeast Alaska. . . . . 269  
*Robert L. Deal*
- Commercial Thinning and Underplanting to Increase Structural and Species  
Diversity in Young Managed Douglas-Fir Stands . . . . . 282  
*Samuel S. Chan, Kathleen G. Maas-Hebner, and William H. Emmingham*
- Reintroducing Fire in Eastside Ponderosa Pine Forests: Long-Term Silvicultural Practices. . . . . 291  
*Andrew Youngblood and Gregg Riegel*

**D3**

---

**Small-Timber Utilization and Markets**

- Veneer Recovery from Small-Diameter Logs . . . . . 299  
*Glenn Christensen and R. James Barbour*
- Hardwood Timber Product Markets: A Focus on Small-Diameter. . . . . 305  
*Bruce Hansen, Phil Araman, Cindi West, and Al Schuler*

**D2, D4, F1, F2**

---

***Faces of Fire in the Pacific Northwest***

- The 100-Year Crusade against Fire: Its Effect on Western Forest Landscapes . . . . . 312  
*Steven Arno*
- Wildland Fire Management for the 21st Century: Evolving Applications and Capabilities . . . . . 316  
*G. Thomas Zimmerman and David L. Bunnell*
- Restoration of Whitebark Pine Ecosystems in Western Montana and Central Idaho . . . . . 324  
*Robert E. Keane and Steve Arno*

**E2**

---

***Assessing Alternative Policy Futures for Oregon's Coast Range:  
The Coastal Landscape Analysis and Modeling Study***

- Forest Fragmentation: Wildlife and Management Implications. . . . . 331  
*James A. Rochelle*
- What Does the Future Look Like? Projecting Landscape Change in Oregon's Coast Range . . . . . 332  
*Pete Bettinger*

**A2, A3, A4, B2, C1, C2, C3, C4, C5, E4**

---

***Landscape Analysis***

- Integrating a GIS and Heuristic Modeling to Achieve Resource Management  
Goals in the Applegate River Watershed, Southwestern Oregon . . . . . 333  
*David H. Graetz*
- Stand Boundary Analysis for GIS . . . . . 340  
*Alexander Evans*
- Long-Range Modeling of Stochastic Disturbances and Management  
Treatments Using VDDT and TELSA . . . . . 349  
*Werner Kurz, Sarah Beukema, Jim Merzenich, Mike Arbaugh, and Susan Schilling*
- A Landscape Simulation Model for Coastal Landscape Analysis . . . . . 356  
*Pete Bettinger*

**A2, A3, A4, B2, C1, C2, C3, C4, C5, E4**

---

**Landscape Planning**

- Forest Restoration in the Sierra Nevada of California: Integrating Economic and Environmental Analysis for Management Direction. . . . . **357**  
*Dominic Roques and Thomas Gaman*
- Integration of Even and Uneven-Aged Management Concepts in a Landscape Plan . . . . . **367**  
*Jeff Boyce*

**F1, F2, F3**

---

**Using Communication to Solve Wicked Resource Management Problems**

- The Role of Communication in Inter-Group Conflict: A Case Study of Permittee–Forest Service Relationships . . . . . **374**  
*Julia Dawn Parker*
- Fair-Open-Honest Public Process . . . . . **379**  
*Tony Faast and Viviane Simon Brown*
- The Pikes Peak Multi-Use Plan Public Process . . . . . **386**  
*Victor T. Eklund Jr., Linda J. Firth, and Steven B. Mullen*
- Resolving a Wicked US Forest Service Resource Management Problem . . . . . **392**  
*Chuck McKinney*

**A2, A4, B2, C3, C6, D4, E2, E5, F3, F4**

---

**Managing Forests at the Urban Interface**

- New Interface Strategies in Florida. . . . . **397**  
*Alan J. Long and Martha C. Monroe*
- Domestic Terrorism: City Problems in Forest Settings . . . . . **403**  
*Joanne F. Tynon and Deborah J. Chavez*
- Managing an Industrial Forest at the Urban-Wildland Interface . . . . . **409**  
*John R. Mount*

**A2, B2, C6, D2, D4, D5, F1, F3, F5**

---

**Natural Resource and Environmental Education: Bridges to Environmental Understanding**

- Information Technology and Youth Natural Resources Education: The Virginia Tech Experience . . . . . **413**  
*Jeff Kirwan and John Seiler*

Environmental Education Efforts to Conserve Biodiversity: A Case from Madagascar . . . . .	418
<i>Michael J. Sirnsik</i>	
Forest Service Camps and Education: Lots of Learning and Fun?—You Bet! . . . . .	425
<i>Macky McClung, Sandy Frost, and Sandy Russell</i>	

**F3, NORCAL SAF**

***Forestry Education Exchange***

Oregon Forest Institute for Teachers: A Forestry Learning Opportunity for K-12 Teachers . . . . .	431
<i>David A. Zahler and Michael Cloughesy</i>	

**B3, E5, F1, F2, F3, F4, F5, Forest History Society**

***Forests & Religion: Perspectives, Influences, and Values***

Effects of Tourism on Perceptions of Wildlife Protection, Religion, and Community Support among Gaeltacht (Irish-Speaking) Commercial Fishers in the Republic of Ireland. . . . .	434
<i>Kathryn Lowe, Susan P. Bratton, and Shawn Hinz</i>	
Religion and Environment. . . . .	442
<i>Mark Stoll</i>	
Faith, Community Values, and Forest Management. . . . .	446
<i>Nancy Lee Menning</i>	
An Overview of African-Americans' Historical, Religious, and Spiritual Ties to Forests. . . . .	452
<i>Earl C. Leatherberry</i>	
Environmental Ethics, Religion, and Forestry in the Southern United States . . . . .	458
<i>Julia Dawn Parker, David M. Zuefle, and Maureen H. McDonough</i>	
An Ancient Model for a New Millennium. . . . .	464
<i>Chuck McKinney</i>	
Spirituality as a Forest Product—An Educator's Views . . . . .	470
<i>John C. Rennie</i>	
Why We Should Not Seek to Re-enchant Science . . . . .	475
<i>Alan G. McQuillan</i>	
Spiritual Values in Leopold's Land Ethic: The Noumenal Integrity of Forest Ecosystems. . . . .	483
<i>Peter List</i>	
Celtic Monks and Forest Protection: Christian Spirituality among the Oaks . . . . .	490
<i>Susan Power Bratton</i>	

## Posters and Student Education Displays

- Development of a Digital Camera Tree Evaluation System. . . . . 495  
*Neil Clark, Daniel Schmoldt, and Philip Araman*
- Agroforestry Technology Transfer in Missouri: Training Multi-Agency Resource Teams . . . . . 498  
*Sandra Hodge*
- Timber Plantations, International Markets, and Forest Conservation . . . . . 503  
*David Tomberlin and Joseph Buongiorno*
- Adaptive Management in Pinyon-Juniper Woodlands of Central Arizona . . . . . 505  
*James R. Soeth and Gerald J. Gottfried*
- Oregon Forestry: In A State of Change, Examining Social Forest Assessments . . . . . 509  
*Catriona M. Armstrong and Rebecca L. Johnson*
- Fixed-Radius Research Plots in Uneven-Aged Stands. . . . . 511  
*Chris W. Woodall and Carl E. Fiedler*
- Forest Geology: How Rocks Affect Forest Nutrition and Health . . . . . 512  
*Mariann T. Garrison*
- EMU and Forest Products Pricing in Europe . . . . . 515  
*Riitta Hänninen, Susanna Laaksonen Craig, and Anne Toppinen*
- Picea Glauca* Height Growth at Five Different Spacings in Interior Alaska: Ten-Year Results. . . . . 517  
*Jamie Hollingsworth and Edmond C. Packee*
- Exploring Natural and Cultural Resource Linkages on a Global Scale —  
An Experimental Learning Approach. . . . . 519  
*Thomas Kuzmic, Edwin Miller, and Stephen Hallgren*
- Multi-temporal Analysis of Deforestation in Honduras Using GIS and  
Remote Sensing Techniques. . . . . 521  
*Samuel Rivera, Luis M. Martinez, and German Sabillón*
- Local Governments as Partners in Natural Resource Management:  
An Adaptive Management Research Design . . . . . 524  
*Timothy D. Schaeffer and Valerie A. Luzadis*
- Prescribed Burning in the South—Acreage, Purpose, and Barriers . . . . . 526  
*Rodney L. Busby, Terry K. Haines, and David A. Cleaves*

Fire in Longleaf Pine Stand Management: An Economic Analysis .....	528
<i>Rodney L. Busby and Donald G. Hodges</i>	
Effects of Elk Depredation on Aspen .....	530
<i>W. David Hacker and Dustin H. Long</i>	
Managing Wilderness Areas within Limits of Acceptable Change .....	532
<i>Chad D. Pierskalla, Dorothy H. Anderson, and David W. Lime</i>	
Java Applets or Applications? How Best to Provide Forestry Data Management and Simulation Modeling Tools .....	534
<i>J.J. Colbert and George Racin</i>	
Utah's Forest Landowner Education Program .....	536
<i>Lisa Dennis Perez and Michael Kuhns</i>	
Restoring the Shortleaf Pine–Bluestem Grass Ecosystem: An Economic Evaluation.....	537
<i>M.M. Huebschmann, T.B. Lynch, D.K. Lewis, and J.M. Guldin</i>	
Characterizing Managed Headwater Forests: Integration of Stream, Riparian, and Upslope Habitats and Species in Western Oregon .....	539
<i>Deanna H. Olson, Samuel S. Chan, Patrick Cunningham, and Bruce Hansen, Andrew Moldenke, Robert Progar, Patricia S. Muir, Bruce McCune, Abbey Rosso, and Eric B. Peterson</i>	
Managing America's Paleontological Resources .....	541
<i>Joseph V.H. Ross</i>	
Online Delivery of Research Products.....	545
<i>Randy D. McCracken</i>	
Clearcuts Burn Hotter: An Analysis of Factors Affecting Fire Severity Levels in Clearcut and Uncut Stands within the Dillon Creek Fire 1994.....	547
<i>Jennifer L. Key and John D. Stuart</i>	
Classification and Description of Old-Growth Redwood Forests in Northwestern California and Southwestern Oregon .....	549
<i>T.M. Mahony and J.D. Stuart</i>	
High Levels of Roundup® and Leaf Beetle Resistance in Genetically Engineered Hybrid Cottonwoods.....	551
<i>Richard Meilan, Caiping Ma, Shuping Cheng, James A. Eaton, Larry K. Miller, Ron P. Crockett, Stephen P. DiFazio, Rosalind R. James, and Steven H. Strauss</i>	

Hypotheses on the Ecological Effects of Alternative Fuel Reduction Methods .....	552
<i>James McIver, Andrew Youngblood, Chris Niwa, Roger Ottmar, and Jane Smith</i>	
Density Management Studies of Western Oregon .....	556
<i>John C. Tappeiner II, Deanna H. Olson, and Charles R. Thompson</i>	
The Hardwood Research Cooperative Program at North Carolina State University.....	558
<i>Daniel J. Robison, Scott X. Chang, and Peter J. Birks</i>	
A Long-Term Study of Ponderosa Pine Seedling Recruitment and Growth under Partial Overstories .....	560
<i>Christopher R. Keyes and Douglas A. Maguire</i>	
The Distribution and Interaction of Red Imported Fire Ants and Native Ants across Ecotones in a Post Oak Savanna .....	562
<i>Rebecca P. Meegan, Sean T. O'Keefe, Robert N. Coulson, and S. Bradleigh Vinson</i>	
Learning about Wilderness: Three Years of Experience in Online Education.....	565
<i>Stephen Peel and Chris Ryan</i>	
Forest Ownership Diversity and Forest Cover Diversity in the Oregon Coast Range .....	570
<i>Brooks J. Stanfield, John C. Bliss, Courtland L. Smith, and Thomas A. Spies</i>	
Minority Meaning Perspectives of Urban Forests and Nature Areas.....	574
<i>Yadong Qi, A.B. Lorenzo, Kevin Drye, and Barbara McDonald</i>	
Innovative Nature-Based Recreation Options in the Ocala National Forest, Florida .....	576
<i>Christine Denny, Taylor Stein, and Janaki Alavalapati</i>	

# **LOGGING IMPACT IN UNEVEN-AGED STANDS OF THE MISSOURI OZARK FOREST ECOSYSTEM PROJECT**

Dr. John P. Dwyer

Abstract. Today, there is keen interest in using alternative silvicultural systems like individual-tree selection, group openings and shelterwood because the general public feels these systems are more acceptable than clearcutting. Consequently, due to repeated entries into forest stands and the fact that residual crop trees have to be carried for a long period of time between re-entries, the damage to residual trees arising from harvest operations has to be better understood so that it can be minimized. The Missouri Ozark Forest Ecosystem Project (MOFEP), located in southeastern Missouri, is a 9,200-acre landscape experiment designed to compare the impacts of even-aged, uneven-aged, and no management on a wide array of ecosystem components. Results from an extensive logging damage study show that careful logging can result in minimal damage to leave trees.

## **INTRODUCTION**

The Missouri Ozark Forest Ecosystem Project (MOFEP), initiated in 1989 in southeastern Missouri, is a 9,200 acre long-term landscape experiment (Figure 1) designed to compare the impacts of even-aged, uneven-aged, and no management treatment regimes on a wide array of ecosystem components.

Following harvest on the MOFEP study sites which took place between the late fall of 1996 and early spring of 1997, researchers gathered logging damage information in the late spring and summer of 1997. Of the total of 648 permanent half-acre research plots located across the 9 research sites, 186 were harvested.

The purpose of this study was to; 1) summarize post-harvest logging impact data following the 1996 harvest of MOFEP sites, and 2) monitor the long-term impact of logging damage on residual tree health and quality.

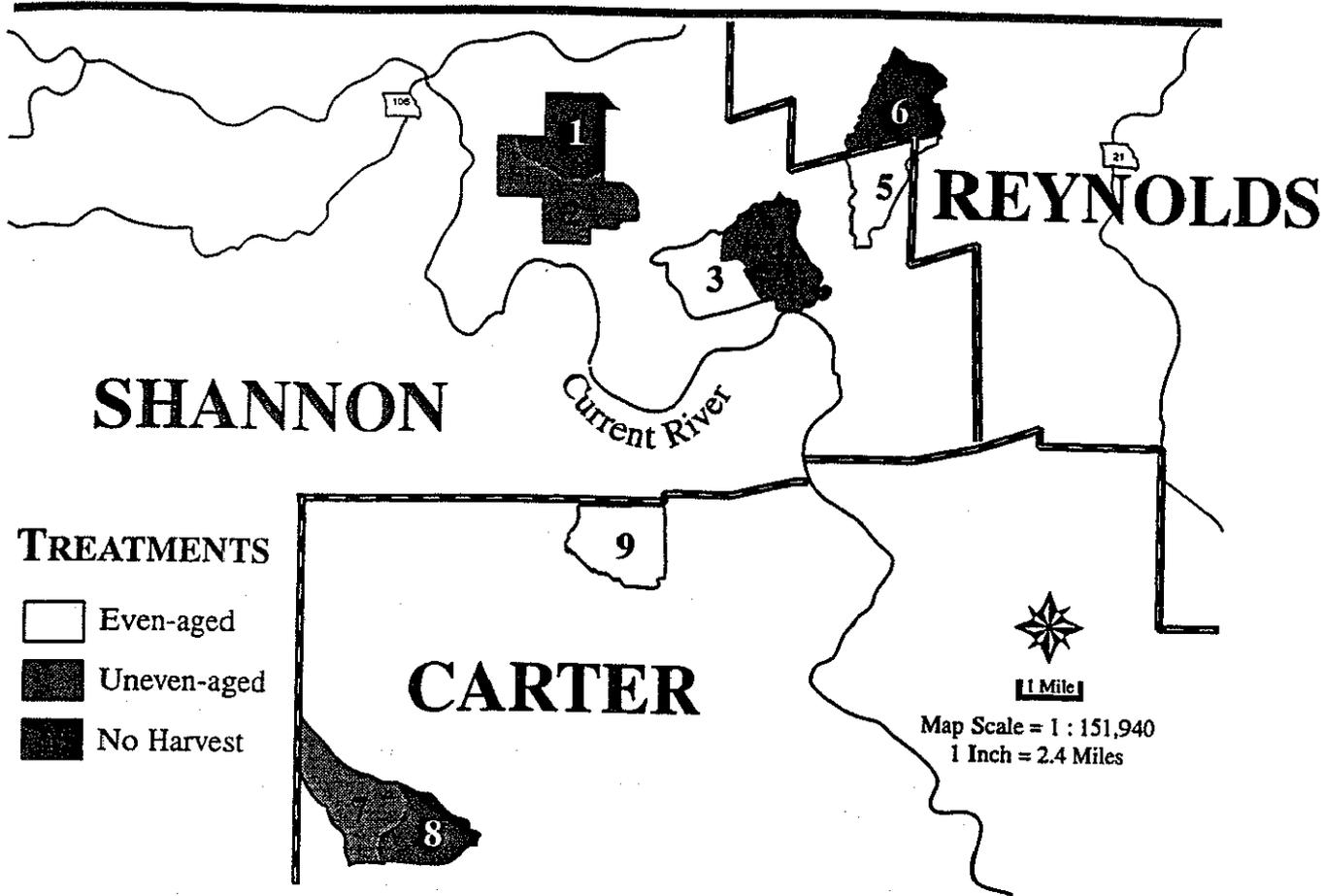
## **PROCEDURE**

Each of the three treatment regimes were replicated on three sites, and each site had to be a minimum of 600 acres in size, contiguous with minimal edge, largely free from manipulation for the past 40 years, and longer, if possible, owned by The Missouri Department of Conservation, located in the southeastern Ozarks, and relatively close to each other (Brookshire et al. 1997).

The MOFEP experiment is designed as a randomized complete block design using nine sites divided into three blocks. Treatments of uneven-aged, even-aged, and no-harvest management were randomly assigned to sites within each block (Sheriff and He 1997). A system of 648 permanent cluster plots was distributed across the nine MOFEP sites. Plots were allocated among forest stands based on stand size with the constraint that each include at least one plot. Each 0.5-acre plot contains a cluster of 4 subplots that are 0.01-acre in size. Plot center for the four subplots is located 56.5 feet



Scale 1 : 15,840  
 1 Inch = 1/4 Mile  
 Contour Interval = 20 Feet



Missouri counties involved

figure 1.

from the center of the 0.5-acre plot and are situated in each of the four cardinal directions.

The research area consists of upland oak-hickory and oak-pine forest communities. Dominant tree species include white oak (*Quercus alba* L.), black oak (*Q. velutina* L.), post oak (*Q. stellata* Wang.), scarlet oak (*Q. coccinea* Muenchh.), blackjack oak (*Q. marilandica* Muenchh.), chinkapin oak (*Q. muehlenbergii* Engelm.), shortleaf pine (*Pinus echinata* Mill.) and hickory (*Carya* spp.). Understory species include dogwood (*Cornus* spp.) and blackgum (*Nyssa sylvatica* Marsh) (Xu et al. 1997).

During 1997 a total of 66 one-half acre plots were harvested on MOFEP sites 3,5, and 9 which are the sites designated for even-aged management. Of the 66 plots, 28 plots were clearcut and 38 received an intermediate thin. The intermediate plots were young even-aged stands that required thinning. Likewise, on the uneven-aged sites 2, 4, and 7 there were a total of 120 plots harvested using single-tree and group selection methods.

## RESULTS

### Areal Impacts

For the clearcut treatment 12 percent of the area was impacted by primary and secondary skid trails (Table 1). On the intermediate plots 9 percent of the area was impacted by haul roads and primary and secondary skid trails. On the uneven-aged treatment plots 13 percent of the area was impacted. A study located in the same general area (Ficklin et. al 1997) found 9.7% of the logged area by was impacted by skid trails.

### Root/Tree Damage

One area of interest concerning harvest on the MOFEP sites was the prevalence of uprooted trees, those residual trees larger than 4.5 inches dbh that were pushed out of the ground by skidding equipment. Twenty-eight clearcut plots were surveyed and there were a total of 3 plots which showed evidence of uprooting (Table 2). On these 3 plots the total number of trees affected by uprooting was 5 which represents about 0.2 percent of the total trees in this treatment. On these 3 plots the mean basal area in uprooted trees is 0.71 square feet per acre which represents about 0.8 percent of the total mean basal area. These 3 plots prior to harvest averaged 93.4 square feet per acre. Likewise, the percentage of uprooted trees was 0.8 percent for both the intermediate and uneven-aged treatments, respectively. On these treatment plots there were a total of 28 and 88 trees that showed evidence of uprooting, and their mean basal area was 1.0 and 0.7 square feet per acre, respectively which, for these two treatments is 1.0 percent and 0.7 of a percent of the total mean plot basal area per acre, respectively.

To determine impact of logging activity on the leave tree, logging activity and damage was measured in terms of whether or not it took place within the drip line of the leave tree, or within a distance of 1 to 1.5 times the crown radius of the leave tree. For example, if the crown radius of the leave tree was 16 feet then any logging activity that took place within that distance was considered to be within the dripline of the tree. For a distance of 16 to 24 feet the activity was considered to

**Area Impacted  
by Trail Type and Treatment**

	Haul Road	Primary Skid Trail	Secondary Skid Trail
Even-aged	0.0	—%— 7.0	5.0
Intermediate (Even-aged)	1.0	6.0	2.0
Uneven-aged	2.0	7.0	4.0

Table 1.

**A comparison of pre-harvest plot conditions versus post-harvest uprooted trees**

	<i>Pre-harvest</i>		<i>Post-harvest</i>	
	Trees Per Acre	Basal area Per Acre	Trees Per Acre	Basal area Per Acre
Even-aged	79.2	93.4	1.7	0.7
Intermediate (Even-aged)	92.1	98.7	1.8	1.0
Uneven-aged	92.0	106.3	1.6	0.7

Table 2.

have taken place within the distance of 1.0 to 1.5 times the crown area of the subject leave tree.

For the uneven-aged treatment 3,145 leave trees were checked (Table 3). Under the table heading, "number of roots damaged" a '0' indicates no damaged roots, a '1' indicates there were some severed roots measured around the leave tree, and a '2' indicates abrasions were observed on roots. Only 0.2% of the trees showed any signs of severed roots, while 0.3 percent showed signs of abrasion. Such low levels of root damage can be explained by the fact that virtually 100 percent of the area that was measured fell in the 0 to less than 4" rut depth category. We don't know how much of the area had no ruts because ruts were measured and recorded in a 0 to 4-inch depth category. Logging was not permitted on erosive soils during wet weather.

### **Bole Damage**

For the even-aged treatment 93.9 percent of the leave trees had no bole wounds (Figure 2), whereas, for the uneven-aged treatment there were no bole wounds on 91.5 percent of the leave trees. For the even-aged treatment 6.1 percent of the leave trees showed 1 or more bole wounds, and the uneven-aged treatment had 8.5 percent of the leave trees with 1 or more bole wounds.

The mean basal area of residual leave trees in the uneven-aged treatment was 56.9 sq. ft. per acre (Table 4). There was 4.8 sq. ft. per acre of basal area in trees that had 1 or more bole wounds. This represents about 8.4% of the total average basal area. For the intermediate thinning, the total average residual basal area was 54.4 sq. ft. per acre. There was 3.2 sq. ft. per acre of basal area in trees that had 1 or more bole wounds, and this represents about 5.9% of the total average basal area. The residual basal area in the clearcut treatment represents pine and hardwood snags that were not harvested.

The mean number of wounds per leave tree is highest in the uneven-aged treatment (Table 5). The higher occurrence of main haul roads in the uneven-aged treatment along with primary skid trails may help to explain the higher number of wounds. It may also be explained by the considerably larger sample of leave trees in the uneven-aged treatment.

The general trend seems to indicate that as the number of bole wounds per tree increases in number, the size of the tree decreases (Table 6). In other words, the smaller the tree the more likely it is to have multiple wounds. The average size of the leave trees with no wounds by treatment is 9.4 inches for the even-aged, 8.7 inches for the intermediate and 9.1 inches for the uneven-aged treatment. The size of wounded tree represents trees in the growing stock classes.

The average height from ground line to the base of the bole wound is 3.0, 2.4, and 3.2 for the even-aged, intermediate (even-aged), and uneven-aged treatments, respectively. The base of the bole wound starts at and extends into the first 8-foot log which represents a significant reduction in value and, quite possibly, the health of the leave tree over time.

For all treatments combined 27% of the bole wounds were in contact with mineral soil. For the intermediate treatment 34% of the trees with bole wounds were in contact with the mineral soil,

**Leave trees with root damage  
within 1½ times the crown radius**

	<i>Number of roots damaged</i>		
	0	1	2
<b>Even-aged</b>	145	0	0
<b>Intermediate (Even-aged)</b>	1074	1	13
<b>Uneven-aged</b>	3128	6	11

Table 3.

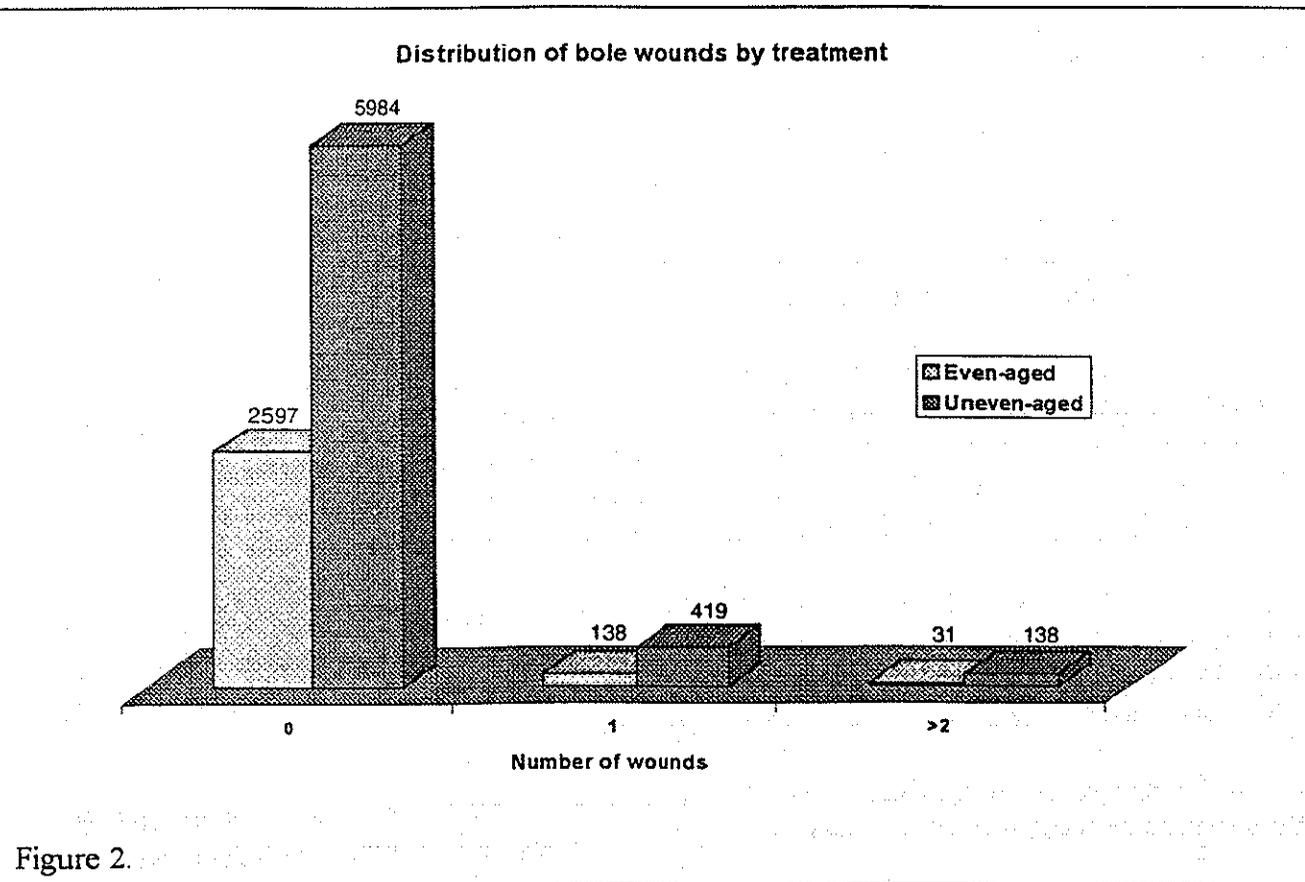


Figure 2.

<b>Mean basal area of leave trees with wound damage</b>					
	<i>Number of wounds</i>				
	0	1	2	3	≥4
	—ft <sup>2</sup> per acre—				
Even-aged	17.2	1.1	0.1	0	0
Intermediate (Even-aged)	51.2	2.6	0.5	0.1	0
Uneven-aged	52.1	3.9	0.6	0.2	0.1

Table 4.

<b>Mean number and size of bole wounds</b>			
Treatment	Wounded Trees	Wound	Size
	(no.)	(no.)	(sq. ins.)
Even-aged	19	1.1	177.9
Intermediate (Even-aged)	150	1.2	106.1
Uneven-aged	557	1.4	140.8

Table 5.

**The average size of wounded leave trees by harvest treatment**

	<i>Number of bole wounds</i>				
	0	1	2	3	≥4
	----- <i>(dbh inches)</i> -----				
<b>Even-aged</b>	9.4	10.4	6.5	—	—
<b>Intermediate (Even-aged)</b>	8.7	8.1	7.6	6.9	—
<b>Uneven-aged</b>	9.1	9.0	8.5	9.1	8.4

Table 6.

and 25% for the uneven-aged treatment.

In the even-aged treatment there were 19 trees that were bole wounded (380 received no bole wound). Of this total, 21% of the leave trees (Figure 3) were in the dominant class and 42 percent in the co-dominant crown class. In the intermediate thinning treatment there were 150 trees that were bole wounded (2,217 received no wound). Six percent of these damaged trees were in the dominant class and 31 % in the co-dominant class. In the uneven-aged treatment there were 557 trees that were wounded (5,977 trees not wounded), of these trees 12 % were in the dominant class and 45 % in the co-dominant crown class.

**Crown Damage**

Over all four crown classes 99% of the leave trees had less than 10% damage to the crown (Figure 4). We don't really know what percentage of the leave trees had zero, or no crown damage, because the crown damage classes were not set up to record these data.

Another way of evaluating the extent of damage is to measure the basal area of leave trees with crown damage. Both the intermediate and uneven-aged treatments had in excess of 99% of their mean basal area per acre in the less than 10% crown damage. Overall, crown damage was minor for either scale of measurement. In a similar study located in the southeastern Ozarks (Ficklin et. al 1997) found that 22.0% of residual trees had some type of logging damage, and 8.6% of the leave trees had crown damage.

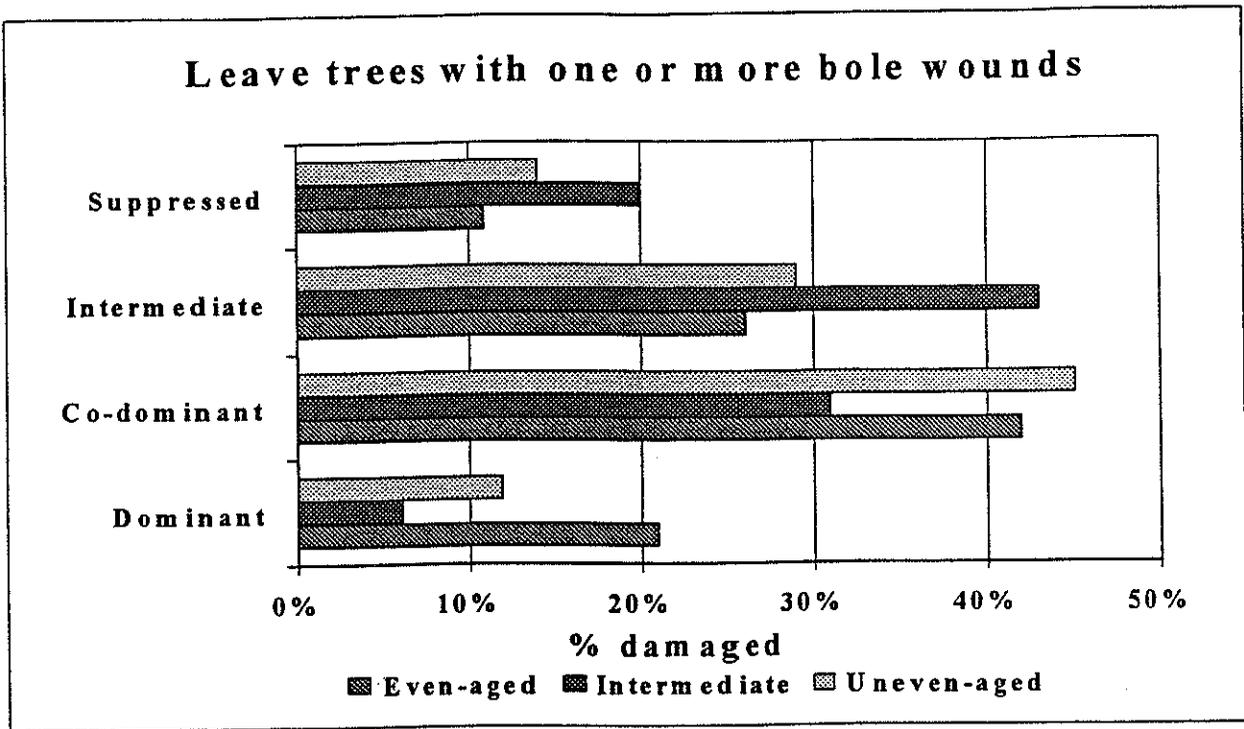


Figure 3.

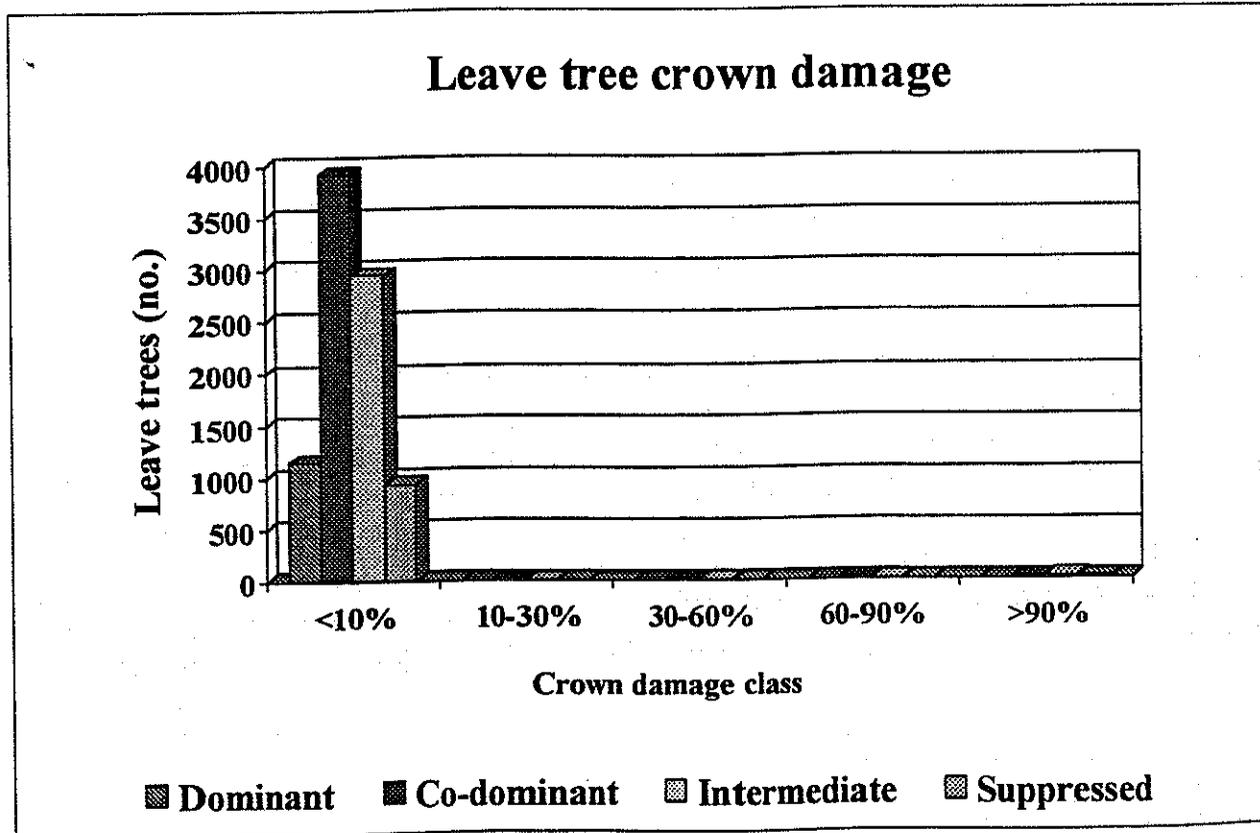


Figure 4

**Indirect effects.** In Figure 5 if one considers the area in blue as the dripline of the leave trees, then almost 37 % have had some type of logging activity. If we add in the distance of 1.5 times the crown radius we pick up another 13 % of the leave trees with some logging activity. In short, 50 % of the leave trees have had some logging activity within a distance of 1.5 times the crown radius of the tree.

In Table 7 logging activity is distributed by logging treatment within the crown radius of the leave tree. The uneven-aged treatment had the highest percentage of leave trees (34.6%) impacted by logging activity within the crown radius. Within 1.5 times the crown area of the leave tree both the intermediate and uneven-aged treatments had the highest distribution, 13.6 and 13.5 % of leave trees impacted, respectively.

Table 8 illustrates the level of logging activity by treatment within the crown radius of the leave tree. Looking at primary skid trails, the percentage of trees whose crowns were within the radius of this activity for the uneven-aged treatment was 51.7% and for the intermediate and even-aged treatment it was 67.0 and 67.3% respectively. Distance from logging activity to the leave tree is critical to protection of the tree. Of all the leave trees that had any activity within 1.5 times the crown radius of the leave tree, the average distance was 11.4 feet.

For a 10.0-inch tree there is about a 1 in 5 or 20 % chance (Figure 6) that it will be wounded if the logging activity is within 5 feet from its bole. For the same tree there is only about a 2 % chance of damage if the activity is 20 feet from the tree. As distance to logging activity increases and tree diameter increases the probability of damage decreases.

## SUMMARY

Group and individual-tree selective harvests will require multiple logging entries. Due to the close proximity of the leave tree to logging activity it is imperative that foresters and loggers work closely laying out skid trails so as to minimize potential damage to crown and bole of leave trees that are retained in the stand.

The relatively low levels of damage to crown and bole of leave trees in this study are the result of a very good logging job. One, I would say, that is symptomatic of a close working relationship between forestry and logging. The fact that forest researchers were on the site, measuring and working with the loggers did insure that relatively low levels of tree damage were achieved.

In the future this project will continue to follow the fate of the trees that were wounded in the initial harvest. It will be the purpose of this study to determine the changes in tree quality and value over time. The economic analysis will consider the profitability of planned careful logging.

### Leave trees impacted by logging activity

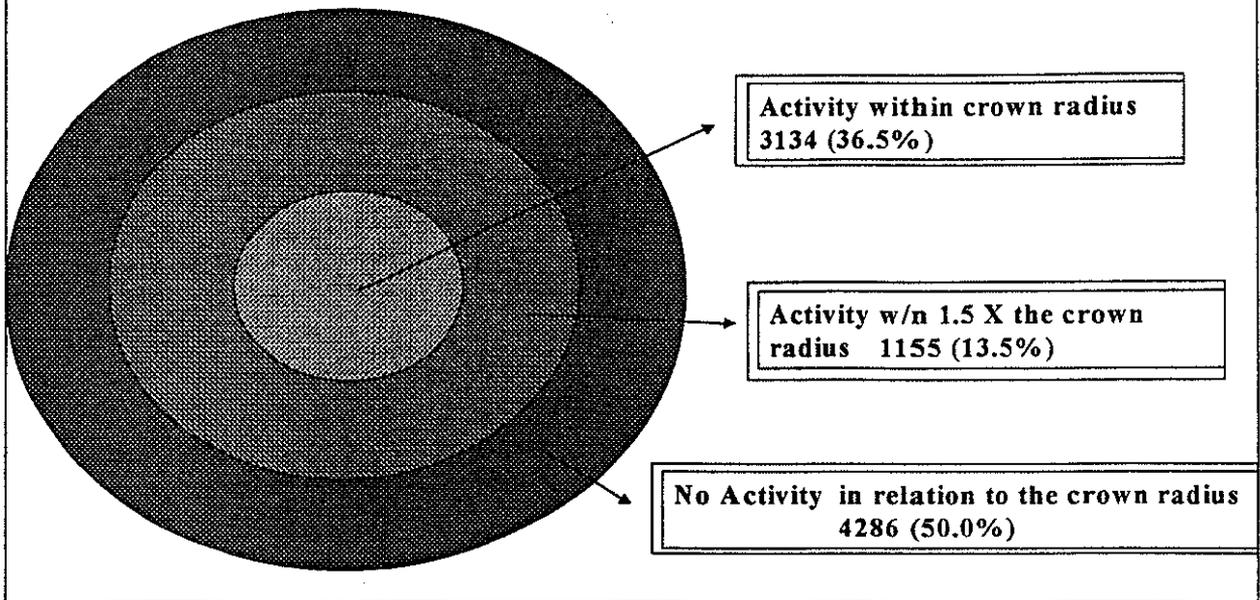


Figure 5.

### Leave trees impacted by logging activity

Treatment	Activity w/n CR	Activity outside CR but w/n 1.5X CR	No activity 1.5X CR
	-----no. of trees -----		
Even-aged	107	32	254
Intermediate	767	321	1279
Uneven-aged	2259	800	3458

Note: CR=crown radius

Table 7.

Probability of having one or more bole wounds in relation to DBH and Distance from the skid trail or haul road.

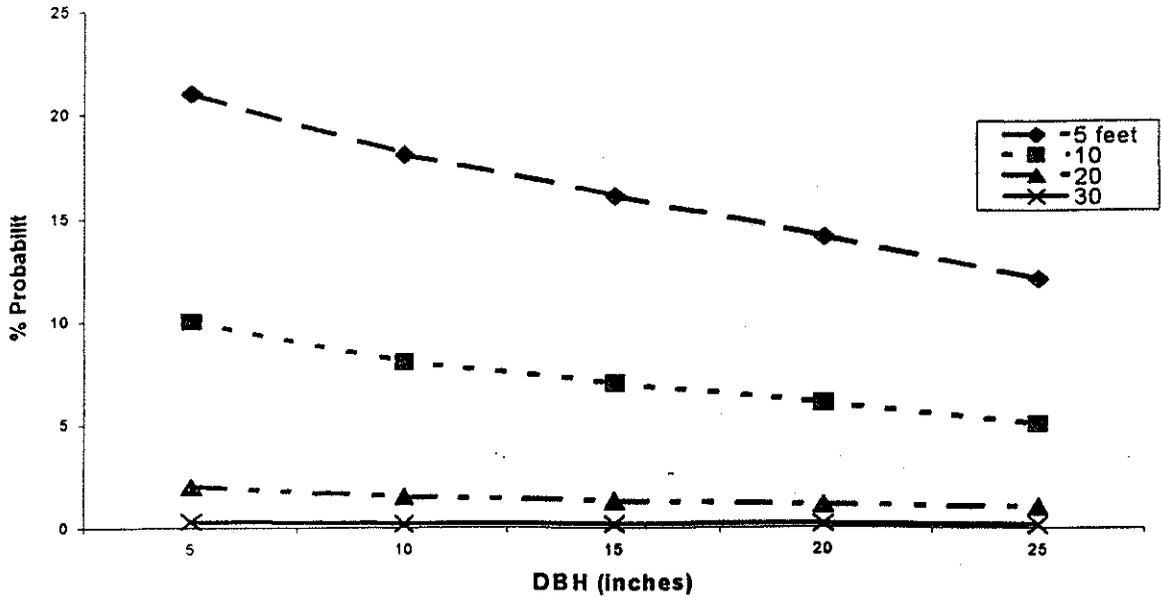


Figure 6.

Leave trees impacted by logging activity inside the crown radius

Logging Activity Level

	1	2	3	4	Total
	-----No. of trees-----				
Even-aged	11	72	21	3	107
Intermediate (Even-aged)	132	514	110	11	767
Uneven-aged	750	1233	258	19	2260
<b>Grand total</b>	<b>893</b>	<b>1819</b>	<b>389</b>	<b>33</b>	<b>3134</b>

Logging Activity Level Key  
 1= 1 or 2 pass skid trail    2= primary skid trail    3= haul road    4= decking area

Table 8.

## LITERATURE CITED

- Brookshire, B.L., R. Jensen and D.C. Dey. 1997. The Missouri Ozark Forest Ecosystem Project: Past, present, and future. USDA For. Serv. Gen. Tech. Rep. NC-193. 378 p.
- Ficklin, R.L., J.P. Dwyer, B.E. Cutter and T. Draper. 1997. Residual tree damage during selection cuts using two skidding systems in the Missouri Ozarks. P. 36-46 *in* Proc. 11th Central Hardwoods For. Conf. Columbia, MO.
- Sheriff, S.L. and Zhuoquiong He. 1997. The experimental design of the Missouri Ozark Forest Ecosystem Project. USDA For. Serv. Gen. Tech. Rep. NC-193. 378 p.
- Xu, M., S.C. Sanders and J. Chen. 1997. Analysis of landscape structure in the southeastern Missouri Ozarks. USDA For. Serv. Gen. Tech. Rep. NC-193. 378 p.

## ABOUT THE AUTHORS

- John P. Dwyer, Associate Professor, Forest Resource Management, Department of Forestry, The School of Natural Resources, University of Missouri, Columbia, MO.
- Daniel C. Dey, Silviculture Research Forester, USDA Forest Service, North Central Experiment Station, University of Missouri, Columbia, MO.
- William D. Walter, Graduate Research Assistant, Department of Forestry, The University of Missouri, Columbia, MO.
- Randy G. Jensen, Research Forester, The Missouri Department of Conservation, Ellington, MO.