Program

2003 Symposium for Systems Analysis in Forest Resources
October 7 – 9, Skamania Lodge, Stevenson, Washington

Onsite registration: Monday 6:00-7:30 pm, Tuesday 7:30-8:30 am, conference wing lobby

Tuesday:

**Stevenson C/D**
- 8:30 – 8:45 Welcome
  - Tara Barrett
- 8:45 – 9:00 Program overview
  - Mike Bevers
- 9:00 – 10:00 Keynote address: “OR in forestry – 20 open problems”
  - Robert Haight
  - Mikael Rönnqvist
- 10:00 – 10:30 Break

10:30 – 12:00 General session:

- 10:30 “The future of spatial optimization in forest resource management”
  - John Hof
- 11:00 “Recent issues and developments in the pulp and paper sector with relevance to forest sector modeling”
  - Peter Ince
- 11:30 “The future of operations research in fire and fuels management”
  - Dave Martell

12:00 – 1:30 Lunch – on your own

**Track A: Baker**
- 1:30 – 3:00 Concurrent sessions: A. Inventory Analysis, B. Sector Analysis, C. Disturbances

**Track B: Rainier**
- 3:00 – 3:30 Break

**Track C: Stevenson C/D**
- 3:30 – 5:00 Concurrent sessions: A. Land Use, B. Carbon Dioxide, C. Simulating Decisions – Teaching

**Baker**
- 5:00 – 6:00 Set-up time for posters

**Hood / Baker**
- 6:00 – 7:30 Icebreaker (appetizers, no-host bar) / informal poster session

Note: Posters may remain up until noon on Thursday.

Assorted beverages will be provided at breaks and for the business meeting in the conference wing lobby.

Note: Room locations could still change. Please check the printed program you will receive at the conference.
Wednesday:

**Track A: Baker**  **Track B: Rainier**  **Track C: Stevenson C/D**

8:30 – 10:00 Concurrent sessions: A. Adjacency, B. Price Uncertainty, C. Fire & Fuels I

10:00 – 10:30 Break

10:30 – 12:00 Concurrent sessions: A. Heuristic Solvers, B. Wildlife, C. Fire & Fuels II

**Dining room**  12:00 – 1:30 Lunch – hosted

**Track A: Baker**  **Track B: Rainier**  **Track C: Stevenson C/D**


3:30 – 4:00 Break

4:00 – 7:00 Field trip – Pacific Northwest Old Growth  Jeff Arthur, Andy Gray

Thursday:

**Adams**  8:00 – 8:45 Business meeting  Matt Pelkki, Joe Roise

8:45 – 9:00 Break

**Track A: Baker**  **Track B: Rainier**  **Track C: Adams**

9:00 – 10:00 Concurrent sessions: A. Information Processing, B. Supply Chains, C. Visualization

10:00 – 10:30 Break

10:30 – 12:00 Concurrent sessions: A. Model Linkages, B. Harvesters – Thinning II, C. Sustainable Forest Management

12:00 – 1:30 Lunch – hosted – *on patio (weather permitting) or Stevenson C/D (if rain)*

**Track A: Baker**  **Track B: Rainier**  **Track C: Adams**

1:30 – 3:30 Concurrent sessions: A. Stand & Forest Optimization, B. Economics, C. Forest Planning

3:30 – 4:00 Break

**Adams**  4:00 – 5:00 General session:

4:00 Closing remarks  Doug Brodie

4:30 Acknowledgments  Tara Barrett, Mike Bevers

4:45 Announcements  Matt Pelkki, Joe Roise
## Summary of Concurrent Sessions by Authors

### Tuesday:

<table>
<thead>
<tr>
<th>Time Range</th>
<th>Track A</th>
<th>Track B</th>
<th>Track C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:30 – 3:00</td>
<td><strong>Inventory Analysis</strong>&lt;br&gt;Baker&lt;br&gt;Mills, Zhou&lt;br&gt;Olofsson et al.&lt;br&gt;Dunham et al.&lt;br&gt;<strong>Sector Analysis</strong>&lt;br&gt;Rainier&lt;br&gt;Latta, Adams&lt;br&gt;DeLaTorre, Newman&lt;br&gt;Moiseyev et al.</td>
<td><strong>Disturbances</strong>&lt;br&gt;Stevenson C/D&lt;br&gt;Acuna et al.&lt;br&gt;Thor&lt;br&gt;Merzenich et al.</td>
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<td>3:30 – 5:00</td>
<td><strong>Land Use</strong>&lt;br&gt;King, Butler&lt;br&gt;Alig&lt;br&gt;(open)</td>
<td><strong>Carbon Dioxide</strong>&lt;br&gt;Woodbury et al.&lt;br&gt;Ahmad et al.&lt;br&gt;(open)</td>
<td><strong>Sim Decisions/Teaching</strong>&lt;br&gt;Bettinger, Lennette&lt;br&gt;Hemm et al.&lt;br&gt;Bettinger</td>
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### Wednesday:

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<th>Track A</th>
<th>Track B</th>
<th>Track C</th>
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<tr>
<td>8:30 – 10:00</td>
<td><strong>Adjacency</strong>&lt;br&gt;Baker&lt;br&gt;Walters&lt;br&gt;Lebel et al.&lt;br&gt;Boston, Bettinger</td>
<td><strong>Price Uncertainty</strong>&lt;br&gt;Rainier&lt;br&gt;Pelkki&lt;br&gt;Penttinen&lt;br&gt;Cox</td>
<td><strong>Fire &amp; Fuels</strong>&lt;br&gt;Stevenson C/D&lt;br&gt;Haight et al.&lt;br&gt;Wiitala, Wilson&lt;br&gt;Greulich, Martell</td>
</tr>
<tr>
<td>10:30 – 12:00</td>
<td><strong>Heuristic Solvers</strong>&lt;br&gt;Nobre, Rodriguez&lt;br&gt;George, McDill&lt;br&gt;ViELma et al.</td>
<td><strong>Wildlife</strong>&lt;br&gt;Gordon et al.&lt;br&gt;Spring&lt;br&gt;Bettinger, Drake</td>
<td><strong>Fire &amp; Fuels</strong>&lt;br&gt;Wilson, Wiitala&lt;br&gt;Kirsch, Rideout&lt;br&gt;Ager et al.</td>
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<td>1:30 – 3:30</td>
<td><strong>Transportation</strong>&lt;br&gt;Coulter, Sessions&lt;br&gt;Marshall, Boston&lt;br&gt;Palmgren, Ronnqvist&lt;br&gt;Sullivan et al.</td>
<td><strong>Reserve Design</strong>&lt;br&gt;Ruble et al.&lt;br&gt;Murray, Wu&lt;br&gt;Haight et al.&lt;br&gt;Nalle et al.</td>
<td><strong>Fire &amp; Fuels/Thinning</strong>&lt;br&gt;Hatfield et al.&lt;br&gt;Kim, Bettinger&lt;br&gt;Fried et al.&lt;br&gt;McGinley et al.</td>
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### Thursday:

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<th>Time Range</th>
<th>Track A</th>
<th>Track B</th>
<th>Track C</th>
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<tr>
<td>9:00 – 10:00</td>
<td><strong>Info Processing</strong>&lt;br&gt;Baker&lt;br&gt;Ribeiro et al.&lt;br&gt;Nobre, Rodriguez</td>
<td><strong>Supply Chains</strong>&lt;br&gt;Rainier&lt;br&gt;Forsberg, Ronnqvist&lt;br&gt;Hultqvist, Olsson</td>
<td><strong>Visualization</strong>&lt;br&gt;Adams&lt;br&gt;Dippon&lt;br&gt;Deem</td>
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<td>10:30 – 12:00</td>
<td><strong>Model Linkages</strong>&lt;br&gt;Hoganson et al.&lt;br&gt;Hyytiainen et al.&lt;br&gt;Monserud</td>
<td><strong>Harvesters/Thinning</strong>&lt;br&gt;Stust Forest Mgt&lt;br&gt;Murphy, Marshall&lt;br&gt;Rauch&lt;br&gt;Forrester et al.</td>
<td><strong>Gunn</strong>&lt;br&gt;Mendoza&lt;br&gt;Maness, Farrell</td>
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<td>1:30 – 3:30</td>
<td><strong>Stand &amp; Forest Opt</strong>&lt;br&gt;Gunn&lt;br&gt;Uusivuori&lt;br&gt;Graetz, Bettinger&lt;br&gt;Cao</td>
<td><strong>Economics</strong>&lt;br&gt;Soth et al.&lt;br&gt;Nalle et al.&lt;br&gt;Turner, Buongiorno&lt;br&gt;Englin, Moeltner</td>
<td><strong>Forest Planning</strong>&lt;br&gt;Gehringer&lt;br&gt;Tahvonen&lt;br&gt;McDill, Lehman&lt;br&gt;Leefers et al.</td>
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Concurrent Sessions

Asterisk indicates corresponding author (when not the first author).
Locations indicated for first authors only.

Session 1: Tuesday, 1:30 – 3:00

**Track A: Inventory Analysis**

**Moderator: Pete Bettinger**

*Baker*

John Mills, Xiaoping Zhou
Pacific Northwest Research Station, Portland, Oregon
“Projecting the future of national forest inventories”

Kenneth Olofsson, Jonas Bohlin, Tomas Lämås, Håkan Olsson *
Swedish University of Agricultural Sciences, Umeå
“Estimation of forest stand parameters using remote sensing single tree detection and field plots with tree positions”

Paul Dunham, Dale Weyermann, David Azuma
Pacific Northwest Research Station, Portland, Oregon
“An investigation of whether land-cover classifications developed from LANDSAT ETM+ imagery can serve as effective substitutes for photo-interpretation for the stratification of FIA’s sample plots”

**Track B: Sector Analysis**

**Moderator: Joseph Buongiorno**

*Rainier*

Greg Latta, Darius Adams *
Oregon State University, Corvallis
“Analysis of an extensive thinning program on eastern Oregon national forest using a dynamic spatial equilibrium market model with endogenous industry capacity”

Rafael De La Torre, David H. Newman *
University of Georgia, Athens
“Assessment of the profitability of intensive silvicultural treatments in the U.S. pulp and paper industry”

Alexander Moiseyev, Birger Solberg, A. Maarit I. Kallio
European Forest Institute, Joensuu, Finland
“Economic impacts of forest plantations in Asia and South America on European forest sector”
Track C: Disturbances

Mauricio Acuna, Cristian Palma, Wenbin Cui, David Martell *, Andres Weintraub
Universidad de Chile, Santiago
“Integrated timber harvest and fire management planning”

Magnus Thor
The Forest Research Institute of Sweden, Uppsala
“Modeling infection and spread of Heterobasidion annosum in coniferous forests in Europe”

James Merzenich, Leonardo Frid, Sarah Beukema
USFS Pacific Northwest Region, Portland, Oregon
“Projecting landscape conditions in southern Utah using VDDT and TELSA”

Session 2: Tuesday, 3:30 – 5:00

Track A: Land Use

Baker
Susan L. King, Brett J. Butler
Northeastern Research Station, Newtown Square, Pennsylvania
“Generating a forest ownership map for Madison County, New York”

Ralph Alig
Pacific Northwest Research Station, Corvallis, Oregon
“Methods for projecting area changes for land uses and land covers: The past and the future”

(Open time)

Track B: Carbon Dioxide

Rainier
Peter B. Woodbury, J.E. Smith, L.S. Heath
Northeastern Research Station, Durham, New Hampshire
“Historical, present, and future estimates of carbon cycling in U.S. forests”

Ismariah Ahmad, E. Zivot, J. Perez-Garcia
Forest Research Institute Malaysia, Kuala Lumpur
“Forest conservation policy and the economics of CO₂ emissions”

(Open time)
Track C: Simulating Decisions – Teaching

Moderator: Larry Davis

Stevenson C/D

Pete Bettinger, Marie Lennette
University of Georgia, Athens
“Extreme policies modeled within the Landscape Management Policy Simulator (LAMPS)”

Martin Hemm, Anne-Katrin Bruchner, Walter Warkotsch
Technical University of Munich, Freising, Germany
“Decision support in German forestry by using industrial simulation software”

Pete Bettinger
University of Georgia, Athens
“A heuristic teaching tool for advanced forest planning courses”

Session 3: Wednesday, 8:30 – 10:00

Track A: Adjacency

Moderator: Alan Murray

Baker

Karl R. Walters
Forest Technology Group, North Charleston, South Carolina
“Interactions of forest structure and spatial restrictions on goal achievement”

Luc G. Lebel, K. Lowell, V. McCullough, M. Renaud, S. Théberge
Universite Laval, Quebec
“Using spatial indices to estimate wood procurement costs for various cut blocks dispersion patterns”

Kevin Boston, Pete Bettinger
Oregon State University, Corvallis
“The ecologic and economic impact of the western states forest green-up constraints”

Track B: Price Uncertainty

Moderator: Darius Adams

Rainier

Matthew H. Pelkki
University of Arkansas-Monticello
“Effects of stochastic prices on dynamic programming formulations”

Markku Penttinen
Finnish Forest Research Institute, Helsinki
“Impact of stumpage price and timber growth risks on optimal harvesting”

Eric S. Cox
Forest Technology Group, North Charleston, South Carolina
“Short-term harvest schedule sensitivity to future stumpage price assumptions”
Track C: Fire & Fuels I

Moderator: Jeremy Fried

Stevenson C/D

Robert G. Haight, Gregory S. Amacher, Arun S. Malik
North Central Research Station, St. Paul, Minnesota
“Estimating the value of fuel treatment on private forest land”

Marc R. Wiitala, Andrew E. Wilson
Riverside Fire Lab, Portland, Oregon
“A systems analysis model for wildland fire preparedness planning”

Francis Greulich, David L. Martell *
University of Washington, Seattle
“Estimating service times for forest fire initial attack airtanker queueing system models”

Session 4: Wednesday, 10:30 – 12:00

Track A: Heuristic Solvers

Moderator: Mikael Rönnqvist

Baker

Silvana Ribeiro Nobre, Luiz Carlos E. Rodriguez *
Athena Management Systems for Natural Resources, Sao Paulo, Brazil
“Analysis and evaluation of the R-ratio heuristic”

Sonney George, Marc McDill *
Pennsylvania State University, University Park
“A new simulated annealing algorithm for solving area-restricted (ARM) forest management problems”

Juan Pablo Vielma, David Ryan, Alan Murray *, Andres Weintraub
Universidad de Chile, Santiago
“Improved solution techniques for multi-period area-based harvest scheduling problems”

Track B: Wildlife

Moderator: Darek Nalle

Rainier

Sean Gordon, K. Norman Johnson, Keith Reynolds, P. Crist
Oregon State University, Corvallis
“Decision support systems for forest biodiversity: A review”

Daniel Spring
Monash University, Melbourne, Australia
“Optimal conservation of neotropical wildlife”

Pete Bettinger, Jason Drake
University of Georgia, Athens
“Examination of trade-offs between timber production and spotted owl habitat in coastal Oregon”
Track C: Fire & Fuels II

Stevenson C/D
Andrew Wilson, Marc Wiitala
Riverside Fire Lab, Portland, Oregon
“An empirically based model for estimating wildfire suppression resource response times”

Andrew G. Kirsch, Douglas B. Rideout *
Colorado State University, Fort Collins
“Optimizing initial attack deployment and placement with simultaneous ignitions in a performance-based system”

Alan A. Ager, Robert McGaughey, Jane L. Hayes, R. James Barbour
Umatilla National Forest, Pendleton, Oregon
“Simulating fuel reduction scenarios on a wildland-urban landscape in northeastern Oregon”

Session 5: Wednesday, 1:30 – 3:30

Track A: Transportation

Baker
Elizabeth Coulter, John Sessions
Oregon State University, Corvallis
“A systems approach to the prioritization and scheduling of forest road investments”

Hamish Marshall, Kevin Boston *
Oregon State University, Corvallis
“The potential for geographical information system logistic planning tools in the forestry industry”

Myrna Palmgren, Mikael Rönnqvist
Linköping University, Sweden
“RuttOpt – an operative transportation planning system”

Janet Sullivan, Greg Jones, Judy Troutwine, Hans Zuuring, Bruce Meneghin, Kurt Krueger
Rocky Mountain Research Station, Missoula, Montana
“MAGIS express: Spatial modeling for timber and access planning”
Track B: Reserve Design

Moderator: Marc McDill

Rainier

Stephanie Snyder, Charles ReVelle, Robert Haight
North Central Research Station, St. Paul, Minnesota
“One and two objective approaches to an area-constrained habitat reserve site selection problem”

Alan T. Murray, Xiaolan Wu
The Ohio State University, Columbus
“Assessing landscape contiguity in reserve design”

Robert G. Haight, Jane A. Ruliffson, Paul H. Gobster, Frances R. Homans
North Central Research Station, St. Paul, Minnesota
“Metropolitan natural area protection to maximize public access and species representation”

Darek J. Nalle, Claire A. Montgomery, Jeffrey L. Arthur, Stephen Polasky
University of Nevada, Reno
“Evaluating gains from increasing model complexity in nature reserve design”

Track C: Fire & Fuels III – Thinning I

Moderator: Marc Wiitala

Stevenson C/D

David C. Hatfield, Marc R. Wiitala, Andrew E. Wilson
USFS Digital Visions Enterprise Unit, Portland, Oregon
“A fast method for calculating emergency response times using travel resistance surfaces”

Young Kim, Pete Bettinger
Oregon State University, Corvallis
“Spatial optimization of fuel management activities”

Jeremy S. Fried, Glenn Christensen, Dale Weyermann, Guy Pinjuv, R. Jamie Barbour, Roger Fight
Pacific Northwest Research Station, Portland, Oregon
“Modeling opportunities and feasibility of siting wood-fired electrical generating facilities to facilitate landscape-scale fuel treatment with FIA BioSum”

Brian McGinley, Allison Reger *, Gary Marsh, Kirk Lunstrum, Jim Mayo
Willamette National Forest, Eugene, Oregon
“Landscape changes from managing young stands: A Fall Creek LSR modeling study”
Session 6: Thursday, 9:00 – 10:00

Track A: Information Processing  
**Moderator:** Matt Pelkki

*Baker*

Rui Pedro Ribeiro, José G. Borges *, Vanda C. Oliveira  
Universidade Técnica de Lisboa, Portugal  
“Developing information systems for Mediterranean forest ecosystem management”

Silvana Ribeiro Nobre, Luiz Carlos E. Rodriguez *  
Athena Management Systems for Natural Resources, Sao Paulo, Brazil  
“A relational data model for the generation of large scale harvest scheduling and forest management problems”

Track B: Supply Chains  
**Moderator:** Kevin Boston

*Rainier*

Mattias Forsberg, Mikael Rönnqvist *  
The Forestry Research Institute of Sweden, Uppsala  
“Integrated logistics management in the forestry supply chain”

Daniel Hultqvist, Leif Olsson *  
Mid Sweden University, Sundsvall  
“A demand based scenario optimization model of the raw material supply to forest industries”

Track C: Visualization  
**Moderator:** Pete Bettinger

*Adams*

Duane R. Dippon  
Bureau of Land Management, Portland, Oregon  
“Cumulative effects analyses with GIS and other visualization tools”

Adam Deem  
Alpine Land Information Services, Inc., Anderson, California  
“Forestry in a box: Visual Forester Professional ™”
Session 7: Thursday, 10:30 – 12:00

**Track A: Model Linkages**  
**Moderator: Stephanie Snyder**

*Baker*

Howard M. Hoganson, Yu Wei, Rickard H. Hokans
University of Minnesota, Grand Rapids
“Integrating spatial objectives into forest plans for Minnesota’s national forests”

Kari Hyytiäinen, Pertti Hari, Tero Kokkila, Annikki Mäkelä, Olli Tahvonen, Juhani Taipale
Finnish Forest Research Institute, Helsinki
“Connecting a stand-level forest process model to economic optimization”

Robert A. Monserud
Pacific Northwest Research Station, Portland, Oregon
“Comparing classes of forest vegetation models”

**Track B: Harvesters – Thinning II**  
**Moderator: Kevin Boston**

*Rainier*

Glen Murphy, Hamish Marshall
Oregon State University, Corvallis
“Adaptive control of bucking on a harvester to meet order book constraints”

Peter Rauch
BOKU – University of Natural Resources and Applied Life Sciences, Wien, Austria
“Estimating the harvesting potential for high mechanized harvesting systems in small scale forestry with a GIS model”

Neal Forrester, Allison Reger, Bruce Meneghin *
Willamette National Forest, Eugene, Oregon
“Assessing short and long term thinning opportunities on the Willamette National Forest”

**Track C: Sustainable Forest Management**  
**Moderator: Marc McDill**

*Adams*

Eldon Gunn
Dalhousie University, Halifax, Nova Scotia
“What is SFM? Adaptive ecosystem management or hierarchical planning? Or something else?”

Gil A. Mendoza
University of Illinois, Urbana
“Participatory modeling and analysis of sustainable forest management: Experiences and lessons learned from case studies”

Thomas Maness, Ross Farrell
University of British Columbia, Vancouver
“Sensitivity analysis of sustainable forest management indicators using multi-objective modeling with fuzzy sets”
Session 8: Thursday, 1:30 – 3:30

**Track A: Stand & Forest Optimization**

**Moderator:** Mike Bevers

**Baker**
- Eldon Gunn
  Dalhousie University, Halifax, Nova Scotia
  “A neuro-dynamic programming approach to the optimal stand management problem”

- Jussi Uusivuori, Jari Kuuluvainen
  University of Helsinki, Finland
  “The harvesting decisions when a standing forest with multiple age-classes has value”

- David Graetz, Pete Bettinger
  Oregon State University, Corvallis
  “Stand-level optimization of ecological goals in eastern Oregon”

- Tianjian Cao
  Finnish Forest Research Institute, Helsinki
  “Optimal harvesting for even-aged Norway spruce stands using an individual-tree growth model”

**Track B: Economics**

**Moderator:** Stephanie Snyder

**Rainier**
- Sándor F. Tóth, Marc E. McDill *, Stephanie Rebain
  Pennsylvania State University, University Park
  “Exploring the efficient frontier of a bi-criteria, spatially explicit, harvest scheduling problem”

- Darek J. Nalle, Jeffrey E. Englin, Kimberly S. Rollins
  University of Nevada, Reno
  “Real options valuation in forest management”

- James A. Turner, Joseph Buongiorno *
  University of Wisconsin – Madison
  “Estimating price and income elasticities of demand for forest product imports from pooled cross-section and time-series data”

- Jeffrey E. Englin, Klaus Moeltner
  University of Nevada, Reno
  “How old is an old growth forest?”
Track C: Forest Planning

Moderator: Doug Brodie

Adams

Kevin R. Gehringer
University of Washington, Seattle
“Nonparametric procedures for defining and using biologically based targets in forest management”

Olli Tahvonen
Finnish Forest Research Institute, Helsinki
“Timber production vs. environmental values with endogenous prices and forest age classes”

Marc McDill, Shawn Lehman
Pennsylvania State University, University Park
“Developing forest management plans for the Pennsylvania Bureau of Forestry”

Larry A. Leefers, L. Jay Roberts, Eric J. Gustafson
Michigan State University
“Spatial sensitivity analysis: An application of HARVEST to a Spectrum alternative”

Poster Session: Tuesday, 6:00 – 7:30

Baker

Moderator: Darek Nalle

Dave Azuma
Pacific Northwest Research Station, Portland, Oregon
“Evaluating fire models: A case study using permanent inventory plots”

Masashi Konoshima, Charley McKetta
Oregon State University, Corvallis
“Combining market and traditional values in tribal forestry using Interactive Forest Decision Synthesis (INFODS)”

Thomas Maness, Ross Farrell
University of British Columbia, Vancouver
“Sensitivity analysis of sustainable forest management indicators using multi-objective modeling with fuzzy sets”

Leif Olsson
Mid Sweden University, Sundsvall
“Optimal road investments – a forest company case study”
Abstracts

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Locations indicated for first authors only.

Mauricio Acuna, Cristian Palma, Wenbin Cui, David Martell *, Andres Weintraub

Universidad de Chile, Santiago

“Integrated timber harvest and fire management planning”

Harvest planners often consider potential fire losses and timber production plans can influence fire management but most timber harvest planning and fire management planning are carried out largely independently of each other. But road construction, timber harvesting and silvicultural activities can influence the flammability of a forest so we are developing an integrated fire and forest management planning methodology that accounts for and exploits such interactions using a fire spread model, a network model that identifies crucial stands that can influence the spread of fires across a landscape and a spatially explicit timber harvest scheduling model. We describe the model and how it is being applied to a forest management unit in the boreal forest region of Canada.
There is a growing interest in applying methods of landscape ecology and simulation to forest management problems. Simulation tools provide a much-needed framework for modeling natural disturbances, forest succession, and management in a landscape context. Specific problems of interest range from studying the effects of natural disturbance on aquatic and terrestrial habitat reserves, developing optimal spatial schedules for fuel reduction treatments, and others. Of particular interest is modeling fuel treatment scenarios on large landscapes to explore ways to reduce wildfire severity within the matrix of resource constraints on Federal lands. This problem has a complex spatio-temporal dimension that must consider the long-term, combined effects of forest management, natural disturbances, and forest succession on resource values of interest. We report on a project to develop and apply more efficient methods to simulate and analyze and visualize landscape-level forest restoration and fuel reduction treatments. We used a proposed fuels reduction project in a wildland-urban interface near LaGrande, Oregon as a case study. The effects of various resource constraints on the economic and operational viability of proposed fuel treatment strategies were analyzed. The longer-term goal of this work is to build a coherent framework of tools and methods that can be used to capture the differences between treatment scenarios in terms of potential wildfire risk, fuel loadings, insect mortality, visual impacts, financial outcomes, and other attributes.
The loss of tropical forests, home of the majority of the world's terrestrial and fresh-water biodiversity is a concern to the international community because of large-scale clearing and net land-use flux of carbon from the terrestrial ecosystem. Commercial logging in virgin tropical rainforests has generated nearly as much concern as has deforestation. Among the issues is how much compensation should be offered to a developing country not to log its virgin rainforests. Existing forest-sector models are inadequate for addressing this issue and most environmental issues associated with tropical forests since these models lack the data that disaggregates forests by virgin and logged-over types. The analytical framework utilizes a forest-sector model comprised of two sub-models—the sub-model of the forest and the sub-model of the industry. The forest sub-model includes timber stock accounts disaggregated into virgin and logged-forests. The accounts estimate timber inventory and log flow for individual years and is linked to timber supply. The industry sub-model is an economic model of demand and supply of timber products in five market sectors. By linking the forest and industry sub-models the study analyzes the impacts of alternative scenarios of logging and forest conversion upon forest product output, employment, and social surplus in domestic wood processing industries and upon net carbon emissions. The model for Malaysia, a key player in the international tropical timber market, is useful as a prototype for other tropical timber producers.
Over the past 25 years, renewable resource assessments have addressed demand, supply, and inventory of various renewable resources in increasingly sophisticated fashion, including simulation and optimization analyses of area changes in land uses (e.g., urbanization) and land covers (e.g., plantations vs. naturally regenerated forests). This synthesis reviews related research over the more than two decades since area projection modeling systems replaced expert opinion approaches in the national Resources Planning Act (RPA) assessments, as part of state of the art approaches for regional and national resources assessments. Such models reflect that key land base changes such as afforestation and deforestation are driven by quite different socio-economic factors. Projections of area changes are important for a wide range of natural resource analyses, including those for wildlife habitat, timber supply, global climate change, water, recreation, and others. The synthesis addresses a remaining significant challenge in the field in general, which is the systematic integration of approaches and therefore findings across resource areas to support sustainability analyses. A remaining challenge is a unified view of future forest conditions constructed at a scale that serves all of these uses adequately. Linkages are examined to other modeling components in a systems analysis approach; for example, feedbacks among assessment models are important in that changes in land uses and land covers affect the condition and characterizations of future forests that influence timber market conditions, while projections of market conditions from supply and demand models feed back into the area change models.
Dave Azuma

Pacific Northwest Research Station, Portland, Oregon

“Evaluating fire models: A case study using permanent inventory plots”

Abstract: The Biscuit Fire in southern Oregon produced national headlines as it burned nearly half a million acres of forest land in late 2002. The Pacific Northwest Forest Inventory and Analysis unit implemented a study in the 2003 field season, remeasuring plots within the burn perimeter to evaluate forest change and establish a pre/post fire dataset to monitor recovery and evaluate fire models. We show some preliminary results based upon the pre-fire data and the Burned Area Emergency Rehabilitation (BAER) fire severity map. Field measurements will include fire severity metrics such as scorch height and ground level scorching.
Pete Bettinger

University of Georgia, Athens

“A heuristic teaching tool for advanced forest planning courses”

This presentation introduces a computer program that allows students to understand how heuristic algorithms are created, and how they behave when solving forest planning problems. The heuristic algorithm teaching tool (HATT) was developed to support an advanced forest planning course at the University of Georgia. The algorithms available within HATT include basic implementations of Monte Carlo simulation, simulated annealing, threshold accepting, tabu search, and genetic algorithms. The Model I forest planning problem that can be solved with HATT is relatively simple: achieve the highest even-flow of timber harvest volume over a three-period planning horizon, using a unit restriction model for 1-period green-up concerns. The number of management units modeled is flexible, as are the yields used to describe forest conditions. The problem size is only limited by a computer's RAM. HATT was developed in Visual Basic, perhaps the most easily understood programming language. A compiled program as well as the programming code itself is available. Students are encouraged to modify the program to enhance the heuristic search processes (e.g., add intensification techniques), to model larger problems (e.g., those with more time periods), or different problems (e.g., maximize net present value, maximize habitat, area restriction adjacency). This presentation was meant to introduce HATT and provide a few examples of the search processes available.
This research describes a model that was developed to allow an examination of the trade-offs between timber production and spotted owl habitat in the Coast Range of Oregon. With this model, called Heuristic Optimization for Owls (HOO), forest management activities (clearcuts) across a 600,000 acre area can be simulated in an attempt to achieve the highest even-flow of timber harvest volume possible subject to several constraints, including minimum harvest ages and clearcut size restrictions. HOO uses the heuristic technique threshold accepting to schedule harvest activities. Harvest activities are scheduled at the parcel level (15-20 acres), yet forest structural condition is tracked at the pixel level (0.15 acres). In addition to variations in minimum harvest ages, the maximum clearcut size can vary, and is modeled using an area restriction method. Further, green-up time periods and riparian rules will be varied, as well as the percentage of pixels left uncut in clearcut harvest units. Spotted owl habitat is assessed using previously published methods (McComb et al. 2002), and production possibility frontiers will be developed illustrating the trade-off between even-flow harvest volume (and associated constraints) and owl habitat levels.
Pete Bettinger, Marie Lennette
University of Georgia, Athens

“Extreme policies modeled within the Landscape Management Policy Simulator (LAMPS)”

The LAndscape Management Policy Simulator (Bettinger and Lennette 2002) was developed for the Coastal Landscape Analysis and Modeling Study (CLAMS) to simulate alternative forest policies within the Coast Range of Oregon. LAMPS allows one to model the behavior of all landowners, over large areas (1.5 million acres at a time), and long time frames (100 years). LAMPS is a Model I strategic planning tool, yet includes several tactical planning aspects, including recognition of green-up periods, clearcut size distributions, interior habitat area development, and riparian and leave tree (within clearcuts) policies. LAMPS is very flexible in what it can model, thus we have chosen to examine some extreme changes in forest policies and their potential impact on timber production possibilities. The extreme policies modeled reflect changes in management that are highly unlikely to occur, yet may help define the bounds of a regional forest management solution space. The policies involve three deviations from the current policy direction of landowners in the Coast Range: (1) treating all land as if it were managed by a single landowner (federal, state, industry, non-industrial private); (2) reducing the maximum clearcut size to 40 acres; and (3) increasing the minimum harvest age to 80 years. Each policy is compared to results from a simulation of current policy, where the behavior of each landowner group (with tailored goals and constraints) is recognized and modeled.
This paper will describe the ecological and economic impacts that result from applying green-up constraints described in the state forest practices rules of California, Oregon and Washington. The analysis uses a two-stage approach to estimate the impacts of the rules on a hypothetical landscape. Stage I allows the development of harvest volumes from a strategic forest planning model using linear programming. These volumes become the harvest targets for stage II, which uses a tactical forest planning model to recognize the green-up constraints. The tactical forest planning model utilizes a heuristic planning technique. The adjacency constraints are recognized using an area-restriction model described by Murray (1999). California limits openings to less than 40 acres for most areas, while Oregon allows 120 acres maximum opening size. Washington has one of the more complex green-up constraints and generally allows openings up to 120 acres. If one of the following conditions have been met, the maximum opening size can be increased to 240 acres: thirty percent of the perimeter is composed of stands whose age is greater than 30 years, 60% of the perimeter is composed of stands whose age is greater than 15 years, or 90% of the perimeter is composed of stands whose age is greater than 5 years. The objective function consists of maximizing net present value. The ecological factors considered will include the maximum and average patch size of closed-canopy forests. One commodity production constraint is employed: meeting some percentage of the target volume suggested by the linear programming strategic plan.
In the present study, the optimal harvesting for a set of even-aged Norway spruce \((Picea abies \,[L.]\,\,\text{Karst.})\) stands located in eastern Finland are studied using an individual-tree growth model.

The optimal solutions are presented separately for artificially and naturally regenerated stands. The results show that two thinnings, thinning from above, and later thinnings, is optimal for moderate density stands (with initial density about 1900 trees per hectare), at 3% rate of interest.

The optimization results show that high bare land values are connected to stands that have large basal areas, tree diameters and dominant heights. The higher the number of thinnings, the lower the thinning intensity. The rotation length in plots giving the highest bare land value is somewhat shorter than in most of earlier studies. However, the results show that optimal rotation may vary considerably (60-99 yrs) at 3% rate of interest depending on the initial stand state.

The optimal solutions are legal at lower rates of interest (0-2%), but illegal at higher rates of interest (4-5%). In the present study, the optimal rotation of Norway spruce was 20-30 years shorter than the recommendations for practice.
Elizabeth Coulter, John Sessions

Oregon State University, Corvallis

“A systems approach to the prioritization and scheduling of forest road investments”

This paper describes ongoing research to create a decision support system to aid in the management of existing forest road networks. At the center of this research is the Analytic Hierarchy Process (AHP). AHP is a multi-criteria decision analysis method that has been widely used in many fields since it was developed in the late 1970’s. However, its use in natural resources is still in its infancy. This tool may be ideal for the prioritization of forest road investments because of its ability to consider multiple attributes, both quantitative and qualitative. A case study will be described that will outline problem formulation and introduce a new method to aid decision makers in refining priorities within the AHP.
Forest planning models have long been used as an essential analytical tool necessary for providing significant information to facilitate effective decision making and planning. Application of these models includes timber harvest scheduling, timberland acquisition and divestiture analysis, long-term sustainable wood supply forecasts, intensive silvicultural investment identification, and the determination of strategic forest management directions. Inherent to the financial analyses conducted with these models are assumptions concerning key financial parameters contained in the model such as discount rates, future costs, and future stumpage prices. Due to the uncertainty associated with projecting costs, interest rates, and timber prices, it is customary to undertake sensitivity analysis of key model parameters to examine the effect on results, and thus to further guide the decision making process.

While projecting timber prices into the future with any accuracy is an extremely difficult exercise, price forecasting is nonetheless a critical part of forest planning analyses. The ramifications of these assumptions over a long planning horizon can be significantly different product flows, activity levels, and cash flows. The purpose of this study is to investigate the impact of different future stumpage price assumptions on the short-term (5-year) timber harvest schedule. Various stumpage price projections were devised, with the resulting short-term harvest schedules compared for purposes of examining how much of the schedule is financially driven. These price projections were applied to case studies of three different southern pine forests (young, balanced, old) to evaluate their influence on short-term timber harvest decisions.
Fiber costs may represent up to 40% of the total cost to manufacture paper in the U.S. The U.S. paper industry must compete with emerging forest countries, located near the equator, whose costs are significantly lower than this. The U.S. could offset these cost disadvantages by incorporating biological technologies and more intensive management regimes, which would lead to improved tree growth, as well as better wood and fiber qualities. In turn, this would maximize processing efficiency, product performance, and give a better economic return.

The forest cost model considers both mill (fiber production) and roundwood (timber production) perspectives. The optimum rotation age is evaluated using bare land value criterion (BLV) in thinned and unthinned management regimes. This model incorporates numerous variables such as stand density, intensive stand management prescriptions with their correspondent growth responses, as well as harvesting and transportation costs. These variables can be modified individually or simultaneously. An integrated Excel spreadsheet, incorporating the latest loblolly pine growth-and-yield models for the Lower Coastal Plain and publicly available cost data, was used to build the model. The model allows for the estimation of the mill-delivered cost of wood under various ‘likely’ scenarios. It, therefore, assesses the profitability of current and potential biotechnological advances. The model also has the ability to determine the land base required for a given size mill.

Multiple scenarios were explored in order to determine factors that optimize profitability and to suggest operating strategies. The findings show that more intensively managed regimes with higher growth rates increase marginal returns. In a commonly used fiber production regime returns were maximized at year 14, whereas returns in a wood production regime (with a thinning at age 10) were maximized at year 18.
Adam Deem

Alpine Land Information Services, Inc., Anderson, California

“Forestry in a box:  Visual Forester Professional ™”

For the past 15 years, Alpine Land Information Services Inc. has been developing site-specific long-term sustained yield plans in the highly regulated California market. Last year the California Forest Products Commission asked them to build a forestry-related educational tool. The President, Donn Zea, asked them to build an interactive simulation to help students learn about the forest and forest products. He wanted the users to interact with a photo-realistic rendering of the forest and have it respond to their Silvicultural commands. Users could pick where in the forest they wanted to harvest, see the visual impact and be presented with a message about how the modern forester guided the forest into the sustainable future.

Once finished, they realized the potential that existed to build a full scale professional simulation that could serve as a cross-discipline communication tool. They saw that Visual Forester Professional™ could be used to tell the story of forest management, both good and bad; that they could give users the freedom to guide the forest for themselves, to step into the shoes of a modern forester. They found that the complexities of forestry can be presented in simple, easy to understand pieces, and that ultimately, anyone with an interest could learn something about forestry.

They’ve put 15 years and 1.9 million acres of experience, insight, and innovation into Visual Forester Professional™. They combined the traditional functionality of a professional growth model with stunning visuals to produce a real-time, interactive, first-of-its kind simulation. Come see it for yourself.
When developing a Resources Management Plan (RMP) for the Bureau of Land Management, the allocation of resources in the form of land use allocations and expected implementation activities need to be described spatially and temporally to support the evaluation of the cumulative effects of alternatives for proposed planning alternatives. In support of a potential land exchange in Western Oregon, a sophisticated model has been developed to evaluate the resulting harvest volumes, inventory values and the impact on a wide range of environmental factors in the form of Habitat suitability Indices (HSI). But what the model failed to provide directly was a presentation of the changing forest age class structure, either spatially, temporally or by ownership. The model calculated all of these factors, but did not report them directly, only reporting the resulting harvest, value and HSI scores. This paper will look at the additional effort required to translate these results their conversion via GIS technology into a set of feature coverages and for presentation into graphics and analyses that provide a more meaningful visualization of the cumulative effects for decision-makers in support of NEPA-based planning.
Paul Dunham, Dale Weyermann, David Azuma

Pacific Northwest Research Station, Portland, Oregon

“An investigation of whether land-cover classifications developed from LANDSAT ETM+ imagery can serve as effective substitutes for photo-interpretation for the stratification of FIA’s sample plots”

Land-cover maps developed from classification of Landsat ETM+ imagery were used to stratify FIA forest inventory plots in selected areas of Oregon and California. These stratifications were tested for effectiveness in reducing sampling error associated with estimates of timberland area and volume compared to estimates developed from stratification by traditional photo-interpretation and to estimates developed without stratification. Study areas were selected so that the methods could be tested both in areas with generally contiguous and closed tree canopy and in areas with more patchy and open tree cover. The land-cover map stratifications were developed from the National Land Cover Data set (NLCD), Classification and Assessment with Landsat of Visible Ecological Groupings (CALVEG), and by using subsets of 1% to 20% of the usual photo-interpreted grid as training points for supervised classifications of the study areas. Strata were created from NLCD, CALVEG, and newly classified layers through the aggregation of cover classes and the creation of ‘edge’ strata by re-classifying pixels at class boundaries or by assigning each pixel a value depending on the number of forested pixels surrounding it. Strata were created from aerial photography by interpretation of a sample grid for land use and cover attributes. Imagery-based stratifications are effective and are less costly than photo-interpretation but in some cases will sacrifice some precision of inventory estimates. The most effective way of developing imagery-based stratifications will vary depending on the properties of the area being stratified.
Jeffrey E. Englin, Klaus Moeltner
University of Nevada, Reno

“How old is an old growth forest?”

Considerable concern exists over the preservation of old growth forests and the ecosystems associated with stands of old growth timber. This analysis examines a detailed ecological data set from the Jasper National Park in conjunction with visitor use data to examine the role of forest age and visitation and recreational value. The analysis finds that the value of a forest continues to grow well past maximum timber yield. Spruce and Lodgepole forest continue to grow in recreational value until they are 300-500 years old. These results suggest that management strategies that focus on shorter term definitions of old growth will result in serious mismanagement of multiple use forests.
Neal Forrester, Allison Reger, Bruce Meneghin

Willamette National Forest, Eugene, Oregon

“Assessing short and long term thinning opportunities on the Willamette National Forest”

The Willamette National Forest conducted an analytical exercise to examine thinning treatments in the short and long term. Objectives of the analysis were to verify short-term thinning estimates; to gain an understanding of long-term implications and capabilities of commercial thinning on the forest; to develop a model to be used for analyzing vegetation management proposals and policies in the future; and to provide useful information about thinning that could be linked with short, mid and long-term management strategies. A linear programming model was constructed, and scenarios with varying mixes of operational and allocation constraints were examined. Where practical, multiple entry prescriptions offered the best prospect of achieving a sustained flow of forest products. Limiting thinning to Late Seral Reserve (LSR) lands or stands previously managed greatly reduces available harvest volumes in the short term. Issues that need further investigation are fuels treatments and management objectives on lands outside of LSRs.
We report on a new platform for decision support systems for logistic problems arising in Swedish forestry. There are many problems arising in the wood chain. One important area is tactical transportation planning. The problem is to satisfy an industrial demand with a given supply at harvest areas and terminals using a number of assortments. The platform developed focuses on integrated wood chains or supply chains where co-ordination between companies and/or organisations and back haulage planning can provide substantial cost reductions. Furthermore, it supports strategic planning where integration/co-ordination of train transportation, terminals and truck transportation is used. The system consists of three parts. First, we have a database with required data relating to harvest areas, industries and terminals. Second, we make use of the new Swedish national road database. Included is the possibility to consider for example road lengths, speed limits, road classes and owners in order to find the most efficient routes. The platform is one of the first applications based on the new national database. Third, we have a number of optimisation modules. Each optimisation module is used to solve a specific problem, for example, integrated backhaulage planning for trucks and train transportation. Within the system there is a number of possibilities to view geographical results. This is an important part in order to be user friendly. Involved in the project are four major Swedish forest companies. These are Holmen Skog, Södra Skog, Stora Enso and SCA. Results from case studies are presented.
Utilization of small diameter trees is viewed by many as the key to making landscape-scale fuel treatment financially feasible. But little capacity currently exists for utilizing such material and capacity of sufficient scale to have a significant impact on the economics of small diameter removals will only be added if sustainable feedstocks can be assured. The FIA BioSum modeling framework which incorporates forest inventory plot data, a transportation cost model, a treatment cost accounting module, and a fire hazard component was applied to a 28.5 million acre study area spanning the Eastern Cascades, Southern Cascades, Klamath Mountains and Modoc Plateau ecoregions of western Oregon and northern California. This area is dominated by forests considered ripe for stand-replacing wildfire. The area amenable to treatment without subsidy was far more limited than what would likely be necessary to achieve substantial reductions in the risk of stand-replacement fire. Sensitivity of this modeling framework to plot density, plot locations and quality of information on road standards was explored to establish the validity of the approach and to guide future application of the modeling framework to other places.
Kevin R. Gehring
University of Washington, Seattle

“Nonparametric procedures for defining and using biologically based targets in forest management”

Forest policy increasingly relies on the use of biologically determined criteria to quantitatively define desirable forest conditions as targets for forest management. Nonparametric procedures for defining targets and performing assessments relative to a specified target have been developed. The effectiveness of the target definition and assessment procedures was examined by applying the procedures to the problem of defining targets for riparian zone forest management. Four assessment scenarios were considered, using 1) basal area per acre, 2) conifer basal area per acre, 3) trees per acre and quadratic mean diameter, and 4) trees per acre, quadratic mean diameter, and average tree height to define targets and then perform assessments. Targets were defined using their respective attributes computed using data from 42 of 127 available riparian plots with age classes in the range from 100 to 180 years. The entire set of 127 plots were then assessed relative to each of the four targets using confidence levels of 95%, 90%, 80%, and 50%. Acceptance percentages computed for each target and confidence level exceeded their nominal values by a factor of at least 2.5. The target definition and assessment procedures were initially developed to address the problem of designing alternate plans under the Forests and Fish Law in western Washington State. The procedures may also be used as a tool for state-space model validation.
Sonney George, Marc McDill *

Pennsylvania State University, University Park

“A new simulated annealing algorithm for solving area-restricted (ARM) forest management problems”

A simulated annealing (SA) algorithm for solving area-restricted (ARM) forest management problems is presented and compared with a SA algorithm for solving problems with unit restriction constraints (URM). The ARM SA algorithm is based on the path constraint structure proposed by McDill, Rebain and Braze (2002). The quality of the solutions obtained with the ARM SA algorithm are compared with solutions obtained with the URM SA algorithm using a designed experiment.
This review evaluates the status of decision support systems (DSS) capable of addressing biodiversity concerns related to forest management. Four objectives are covered by the study: the identification of available tools, research into their actual use, discussion of the transferability of these systems, and recommendations for future research and development. Over 100 tools were identified from previous reviews and interviews with DSS experts. These tools were screened and prioritized for their usefulness in forest biodiversity decisions. Standardized descriptions were created for the top tier of systems using information from print and online sources, as well as developer and user interviews. To identify future development needs, separate panels of interviews were conducted with national biodiversity experts and forest management decision makers. The issues identified by these groups were then compared to the current capabilities and development plans from the review of available systems. First, we found a mismatch between top issues identified by the expert/decision maker groups (development, climate change, invasive species) and the predominate focus of forest decision support tools on harvesting. Second, few DSS appear to be adapted yet for use within the popular biodiversity evaluation frameworks of forest certification and the Montreal Process Criteria and Indicators.
A stand-level optimization procedure, using a RLS-path algorithm, was developed to allow the development of management prescriptions that address ecological goals for eastern Oregon forests. The procedure requires that stand-level goals be defined by basic tree-level data (e.g., basal area, trees per acre, species, etc.). It then seeks to minimize the deviations of stand conditions relative to these goals over a 100-year time frame. Two main options are available, depending on the policy being modeled: either a minimum harvest volume is required, or it is not required. When prescriptions are suggested for private lands, the minimum harvest volume constraint seems reasonable, however, in consultation with federal land managers, the minimum harvest volume constraint was not as critical, since the focus there is on fire hazard reduction, and not necessarily economic efficiency. [A user-friendly GUI program (called SLOMO) was developed to allow managers the ability to change weights and other coefficients and which will be presented at the conference.]
Francis Greulich, David L. Martell *

University of Washington, Seattle

“Estimating service times for forest fire initial attack airtanker queueing system models”

Initial attack airtanker systems can be modelled as spatial queuing systems but in order to do so one must estimate the travel time component of the service time which includes the time required for an airtanker to fly from its base to the fire, fight the fire and return to its base. Mean service time calibration methods that have been used to estimate travel times for urban emergency response queueing systems are based on an assumption that all fires are located at nodes located at the centres of relatively small polygons that cover the protected area. We use an exact method that accounts for the fact that fires are distributed across the larger polygons characteristic of forest fire management systems and we compare our results with the traditional node approximation procedures.
“A neuro-dynamic programming approach to the optimal stand management problem”

We consider the problem of optimally managing a stand containing two or more species. Most reasonable growth models require as state information, height (or age), basal area, and stand total diameter as well as an indicator variable giving treatments that have been performed on the stand. Thus, even a two species stand will require at least 8 state variables, six of which are effectively continuous. A number of researchers have developed sophisticated forward dynamic programming and related algorithms to solve problems of this nature. However, our interest is in problems that are inherently stochastic, in their basic growth dynamics, in market prices and in disturbances ranging from insects to fire to hurricanes.

The algorithms that we are interested arise from two sources. The one is the stochastic control community who have long used various types of dynamic programming approximations in the design of suboptimal control. The second is the artificial intelligence community who have viewed large scale multi stage decision problems from a perspective of learning algorithms in what is generally referred to as re-inforcement learning theory. Neuro dynamic programming is a term which encompasses both these lineages.

In this talk we review the issues of applying these ideas in the context of some fairly simple one and two species harvesting problems, with a view to eventual application to more complex problems.
Eldon Gunn

Dalhousie University, Halifax, Nova Scotia

“What is SFM?  Adaptive ecosystem management or hierarchical planning?  Or something else?

Most observers, although they may agree on little else about sustainable forest management (SFM), agree that it involves making multi-criteria decisions about large scale, fundamentally stochastic systems, whose actual state is only imperfectly known and whose underlying dynamics are also only imperfectly known.  In contexts, such as the Canadian CCFM or the international Montreal protocol, SFM involves measuring and managing for biodiversity, ecosystem health and productivity, soil and water, global cycles, multiple economic benefits and social responsibility.

Adaptive Management has at its heart a control approach with an emphasis on taking actions aimed primarily at understanding the underlying systems dynamics and stochastics before switching to actions designed to exploit the knowledge acquired to maximize some overall system benefit.

Hierarchical planning aims at recognizing the fundamental multi-level nature of complex systems which necessitate a simplified, usually somewhat deterministic viewpoint for central, large scale control, with other actors presumed to be able to take recourse with regard to the stochastic events they are encountering, while taking account of the constraints imposed by the central decisions.

Both of these paradigms can be characterized by a view that, in the end, there is some sort of central value system that is capable of creating a total order on the overall set of outcomes and hence defining a concept of optimal.  It is not clear that such a viewpoint is compatible with the SFM paradigms.
Private forest land subject to fire risk occurs throughout the United States. Further, many of these forest parcels include permanent or seasonal homes. Estimates are needed of the economic value of fuel treatments in this type of forest. Using a Faustmann framework, we formulate a stand-level model with decision variables for planting density, the timing and intensity of fuel treatment, and rotation age. Fire enters the model as a homogeneous Poisson process with annual arrival rate independent of stand age. If a fire occurs, it can destroy the trees and structures; however, fuel treatment prior to the fire increases salvage value of timber and prevents loss of structures. The landowner is assumed to choose the values of the decision variables to maximize the discounted value of timber and non-timber benefits. The baseline Faustmann model is solved to maximize bare land value without fire risk or non-timber benefits. The baseline model is then modified to include non-timber benefits and determine the impacts of incrementally increasing the level of fire risk. For each level of fire risk, results are compared with and without fuel treatment. Further, the models are also used to estimate the value of informing landowners about fire risk and reducing the cost of fuel treatment. Results are presented for loblolly pine stands in the southeastern United States.
Robert G. Haight, Mikael Rönnqvist

North Central Research Station, St. Paul, Minnesota

“OR in forestry – 20 open problems”

Abstract forthcoming.
Robert G. Haight, Jane A. Ruliffson, Paul H. Gobster, Frances R. Homans

North Central Research Station, St. Paul, Minnesota

“Metropolitan natural area protection to maximize public access and species representation”

In response to widespread urban development, local governments in metropolitan areas in the United States acquire and protect privately-owned open space. We addressed the planner’s problem of allocating a fixed budget for open space protection among eligible natural areas with the twin objectives of maximizing public access and species representation. Both objectives were incorporated into a discrete, 0-1 integer optimization model and applied to a problem with 68 sites, 61 species, and 34 towns in the Chicago metropolitan area. Increasing required species representation reduced the maximum number of towns with access to reserves, and the tradeoff between species representation and site accessibility increased as the budget was reduced. The definition of site accessibility affected optimal reserve design. A town had access if a specified number of reserves was located within a specified distance from the town. Increasing the distance standard resulted in more, smaller sites protected in a uniform spatial pattern. Increasing the minimum number of sites required to be within a distance standard caused the selection of clusters of sites near a few towns. The study adds a new dimension to reserve site selection models by including site accessibility as a goal.
This paper presents an algorithm to quickly calculate minimum travel times between locations. The algorithm was developed for integration into wildfire planning simulation models. During a simulation, these models need quick estimates of suppression resource travel times to fires from indeterminate locations to select resources with the earliest arrival times. While generally quite fast, network-based minimization algorithms are not inherently designed for the wildfire problem since the fires often are not located near existing network features, such as roads and trails. On the other hand, traditional raster-based Least Cost Path algorithms can take minutes, if not hours, to calculate each resource’s travel time, too slow to be effective within a simulation model. The algorithm presented in this paper employs a multi-resolution raster-based approach to calculate each travel time in a fraction of a second with a limited loss of accuracy.
Martin Hemm, Anne-Katrin Bruchner, Walter Warkotsch

Technical University of Munich, Freising, Germany

“Decision support in German forestry by using industrial simulation software”

On today’s global timber market, German Forestry has to deal with increasing competition, falling timber-prices and constantly rising harvesting costs. Cost cutting and improved customer orientation is required to retain profitability. Like in many other industries, these goals can be achieved by an improvement of logistics, often supported by user-friendly optimization software.

The basic idea is to apply industrial simulation software in the wood-supply-chain and modify it in order to develop a decision support tool for the right choice of the operating system and the assortments produced.

Simulation software is designed to analyse, plan and control material handling systems. In forestry it assists the user to find the most efficient machine combination depending on cruise data of the stands. Results show that it is possible to use industrial simulation software to model and analyse different kinds of operational scenarios in forestry. Additionally advantages and disadvantages of economical and technical impacts of different logging processes can be shown. First simulation models have delivered results containing productivity, costs and energy consumption. By analysing and comparing the output of different models, the simulation software can be used as decision support system.
This presentation will provide an overview of the state-of-the-science in spatial optimization of landscape pattern and to suggest research questions that are most critical for moving forward in the field. It is currently possible to capture deterministic characterizations of the most basic ecological spatial relationships: proximity relationships (including those that lead to edge effects), habitat connectivity/fragmentation relationships, population growth and dispersal, and patch size/habitat amount thresholds. Spatial autocorrelation can also be captured probabilistically in chance-constrained formulations and can be incorporated into models addressing the other spatial relationships just listed. General treatment of stochastic variables in spatial optimization is in its infancy. Improved understanding and prediction of organism movement is the most fundamental ecological research need to support spatial optimization. Addressing landscape management problems involving multi-species objective functions and complex interactions between individuals or between species is currently beyond the state-of-the-science. These problems will require very creative optimization approaches that may be heuristic and open-ended in nature and thus can only suggest “good” landscape arrangements rather than truly optimal layouts. Synthesis of existing capabilities and monitoring methods for implemented spatial plans are also needed.
Howard M. Hoganson, Yu Wei, Rickard H. Hokans
University of Minnesota, Grand Rapids

“Integrating spatial objectives into forest plans for Minnesota’s national forests”

The Chippewa and Superior National Forests in Minnesota released their draft forest plans in May, 2003. Analyses for the plans used the University of Minnesota’s Dualplan forest management-scheduling model. Additional modeling work is being done to refine schedules using a spatial model based on dynamic programming to address explicitly the area of old forest interior (core) area produced over time in each major landscape ecosystem. This paper will describe recent experiences in linking a spatial model with a large-scale forest management-scheduling model that can address a wide-range of other forest-wide constraints. Applications involved 60,000-100,000 analysis areas with potentially thousands of treatment options per analysis area. A key aspect for practical application has been in trimming the list of possible treatment options for each analysis area while minimizing potential impacts of such trimming on the optimality characteristics of the spatial solutions. Potential linkages between broad strategic planning and future plan implementation will also be discussed.
The raw material supply to a mill usually has many sources in Sweden. The decision maker can procure raw material from the own forest, buy from small forest owners, swap with other operators or purchase at the international market. Wood chips to pulp mills are bought from sawmills and have their own transportation system. Optimizing the raw material supply on a tactical planning level is a challenging task, and can only be managed properly if uncertainty aspects are considered. The solution will otherwise give no options when disturbances occur. The deterministic equivalent of the scenario model is formulated and solved as a mixed integer quadratic model. In this paper we have focused on model building and estimation of costs since this is challenging in itself. The model is tested on one small and one medium sized problem. Moreover, we have compared solutions under uncertain weather conditions with purely deterministic solutions. This is in itself very important, since it gives the value of hedging, and measures solution uncertainties. We also show how to simulate and evaluate different strategies in the raw material chain, from harvest operations to the delivery at the mills. In our study the medium sized problem is solved in reasonable time with commercial software, and the solutions indicates that the hedging effect should not be underestimated. Future work will be development of stochastic programming algorithms to solve large scaled instances of the problem using parallel computing.
In this study a detailed process-based description of growth is combined for the first time to economic optimization model. Economics of timber production is investigated by using a distance-independent individual-tree process model specified for a pure even-aged Scots pine (\textit{Pinus sylvestris} L.) stand. Stem taper and crown morphology information are used for bucking the harvested trees into several roundwood categories according to prevailing requirements applied in the Finnish timber markets. Sensitivity analyses for different rates of interest and roundwood prices are conducted in order to analyze the underlying economic and ecological determinants of optimal harvests and long-run timber supply. Our results imply that economic activity decreases total biomass production, but makes the production process of roundwood more efficient. Detailed description of timber quality has strong effects on optimal thinnings and timing of clearcutting. The first thinnings, for example, are light irrespective of the applied rate of interest due to their favorable feedback effects on the quality of the residual trees. Production of the highest-grade roundwood is rational only at lower rates of interest than prevailing in the capital markets. The objective function surface is highly nonmonotounous due to discontinuous shifts of timber volume between roundwood categories. As a one consequence of this, optimal rotation is insensitive to changes in the rate of interest higher than 4%. Nonmonotounous value growth is also shown to lead to the existence of multiple optimal solutions at some economic parameter values.
Forest sector modeling can encompass the pulp and paper sector, particularly in modeling nationwide trends in resource use, value, and trade. Modeling those trends has some relevance in assessing future sustainability of resource management and multiple socioeconomic benefits of forestry at the national or regional level. In that context some significant issues and developments have arisen over the past decade. Among recent developments with particular relevance in the United States are expansion of pulp and paper capacity overseas, diminished capital investment and capacity growth in the United States, expansion in paper recycling domestically with expanded export of recycled fiber, weakness in domestic demand for paper and paperboard associated with weakness in the manufacturing sector and mature product markets, declines in pulp and paper product exports and rising imports, diminished employment in U.S. pulp and paper mills, rapid expansion in productivity of wood fiber plantations overseas coupled with expansion of softwood plantations in the United States, and declines in wood pulp output, pulpwood demand, and the market value of pulpwood, reducing economic feasibility of forest management in some regions and diminishing the overall contribution of forestry to U.S. GDP. These trends can be characterized as issues of industry globalization, consolidation, and competitiveness. This paper explores the capability of existing forest sector models to analyze these issues, and considers the propensity for such issues to remain relevant and important in the near future. On that basis a set of general recommendations are made for future forest sector modeling related to the pulp and paper sector. Recommendations encompass modeling product demand, modeling trade and regional competitiveness, modeling capacity growth, and modeling wood fiber supply and demand.
The spatial and temporal arrangement of fuel management activities at landscape-scale can possibly modify wildfire behavior and thereby reduce undesirable consequences of wildfires. The fuel management treatment in individual units can be expected to modify fire behavior at a local scale, but alone, may have negligible impact on the overall growth and behavior of larger fires at much larger scales. Research has shown that cumulative effects of individual fuel management treatment units depend heavily upon their spatial pattern. The development and comparison of methods for scheduling fuel management activities, both temporally and spatially across a landscape, is the objective of this research. Forest management plans were developed based on a multi-objective problem which sought to minimize the deviations between actual harvest volume and a harvest volume target (thus seeking to obtain an even-flow of timber harvest volume), and minimize deviations between the spatial location of activities and models that best describe the spatial patterns. Four spatial patterns of management activities were modeled, with emphasis on the placement of activities in the first few time periods. Two heuristic scheduling techniques, the great deluge algorithm and the tabu search, were used to develop the forest management plans. The spatial patterns of activities included: random, dispersed, clustered, and gridded. Results, which are forthcoming, will indicate the relative effectiveness of a spatial pattern with respect to harvest volume and fire behavior. FARSITE (Finney, 1998) will be used to evaluate the effectiveness of the schedules on resulting fire behavior.
It is well documented in the literature that the size of forested landholdings directly impacts the management of forest resources. Traditionally, the data has been presented in tabular format. A spatial format will provide a more useful mechanism for summarizing and utilizing this important information and can provide new insight into the causes, or at least correlates with differences in sizes of forest landholdings. The objective is to create a map that depicts the size of forest landholdings across the United States. The dependent variable, the size of forested landholdings is derived from the USDA Forest Service Inventory and Analysis’s ownership survey data. By identifying the owners of forested plots located on a fixed grid, we are able to count the number of plots owned by each individual and use this as a first approximation of the size of forested landholdings. While this approach works adequately for ownerships with larger forested landholdings (e.g., greater than 12,000 acres), it can not be used to differentiate among ownerships with smaller landholdings. Here information from the ownership survey can be used to develop more precise values to the size of forested landholdings. The independent variables to be tested come from a variety of sources including remotely sensed images, elevation models, and population statistics. Madison County, NY was selected as a test case because a digitized ownership layer was available, which allows for the precision of the estimation techniques to be accurately assessed. Decision tree techniques have proven to be the best modeling technique so far and the accuracy of the prediction map will be generated using enhanced kappa statistics developed by Pointus.
Recent changes in fire management have created a demand for a new fire program analysis model that can be used to manage initial attack deployment and budgets. Fire managers and budget appropriators seek a model that will quantify and display tradeoffs in program effectiveness at alternative funding levels. To address these issues, we used a non-monetized cost effectiveness analysis (CEA) framework and created an Integer Program that maximizes initial attack effectiveness for a given funding level. The model optimizes the initial attack organization for a user defined set of fires. Contributions include the inclusion of simultaneous ignitions, optimal location of resources, split fire seasons, varying fireline production rates, and varying rates of fire perimeter growth. The model is intended to be compact and robust to promote cost effective use of limited budgets and to address issues of accountability in federal fire programs.
Masashi Konoshima, Charley McKetta

Oregon State University, Corvallis

“Combining market and traditional values in tribal forestry using Interactive Forest Decision Synthesis (INFODS)”

The Nez Perce Tribe balances a mix of timber and non-timber outputs and considers their cultural significances. Mathematical programming was applied to demonstrate how a preferable output mix and production levels can be identified without explicitly quantifying their relative preference structure. The multiple objective linear programming (MOLP) model combines market values and the tribe’s cultural values using a composite objective function originally developed by Liu and Davis in 1995. The Forest Resource Department of the Nez Perce Tribe is assumed as a single decision maker for the tribe. The process seeks where the decision maker’s marginal rate of substitution matches the marginal rate of transformation. Interactive processes with a series of hypothetical post-optimal analyses are conducted to find that the output mix production level reflects tribal preferences.

This demonstration confirmed that the MOLP model with feedback processes can mathematically identify the decision maker’s preferable solutions, while the model without feedback process may fail to provide those. This demonstration model balances resource output mix and production levels according to decision makers’ preferences. Two to three cycles of interactive processes with hypothetical post-optimal analyses significantly reduces decision spaces and reaches solutions that cannot be improved. Although single solutions may not be obtained, all accepted solutions are non-dominated. Silvicultural prescriptions that are common in both public and private sector local forestry are less preferred in accepted tribal solutions.
Greg Latta, Darius Adams *

Oregon State University, Corvallis

“Analysis of an extensive thinning program on eastern Oregon national forest using a dynamic spatial equilibrium market model with endogenous industry capacity”

The eastern Oregon forest products sector is an industry in decline. Precipitated by the near elimination of national forest harvest, the sector has lost more than half of its processing capacity since the early 1990’s. Based on private timber resources alone, this study projects a further halving of mill numbers over the next two decades. In the face of growing concerns about forest health and fire hazard/fire behavior modification, programs of extensive thinnings to reduce volumes in overstocked stands on national forests have been proposed. This paper employs a dynamic, spatial equilibrium model of the eastern Oregon log market to examine the potential harvest, price and capacity impacts of such programs. Unlike past studies, total harvest, market prices, flows from woods to mills, and volumes processed by processing center are endogenous, as are management investment (silvicultural) decisions on private lands. Geographic locations of timber harvest sources and log processing centers are explicit and connected by transportation costs. Decisions to maintain, expand, contract or close processing capacity are also endogenous based on costs and profit potential. National forest thinning options are introduced as additional, geographically specific harvest sources. The analysis provides estimates of the effects of a thinning program on mill locations and processing capacity and of the proportion of national forest thinning opportunities that could be economically exercised.
Cutting blocks are increasingly being dispersed over large procurement areas. The spreading of harvest operations increases procurement costs. Predicting these costs is time-consuming because a precise harvesting plan usually has to be established to adequately measure forest logistics parameters such as total road distance and cut-block size. In an attempt to make the management scenario evaluation process more efficient, a new GIS-based method for estimating the costs of forest operations was developed. This method uses spatial indices to predict key wood procurement parameters such as harvesting, road construction and maintenance, and transportation costs based on the values of a series of spatial indices that effectively characterize a procurement area. Cost functions based on the relationship between spatial indices that quantify factors such as cut-block dispersion and landscape heterogeneity, and operational factors such as skidding and hauling distance were developed through multiple regressions. Eventually, using a selection of spatial indices, operational guidelines could be established to quantitatively describe wood procurement areas and generate harvesting patterns that minimise costs while meeting a set of forest management related constraints.
Larry A. Leefers, L. Jay Roberts, Eric J. Gustafson

Michigan State University, East Lansing

“Spatial sensitivity analysis: An application of HARVEST to a Spectrum alternative”

The Chequamegon-Nicolet National Forests in northern Wisconsin have developed forest plan alternatives using Spectrum. Related spatial analyses using HARVEST (Gustafson and Rasmussen 2002) were completed to provide a spatial context for proposed management. Metrics related to forest interior, forest edge, and patch size were reported. For these alternatives, standard assumptions were used for defining forest openings, harvest sizes, harvest dispersion, green up intervals, and buffers. However, the sensitivity of the spatial solution to these assumptions (often management guidelines) was not examined. For example, what are the spatial effects of expanding no-cut buffers around streams? This paper provides an in depth examination of the effects of modifying the assumptions on the feasibility of the optimal Spectrum solution for one alternative. In some cases, the spatial sensitivity will require new, more constrained Spectrum solutions in order for spatial feasibility to be achieved.
A multi-objective linear programming model was developed for forest-to-product planning by a forest products company operating in the Invermere Timber Supply Area in Southeastern British Columbia. The overall model consists of two sub-models connect in a hierarchical framework.

The forest development sub-model is formulated for both timber and non-timber resources, and includes fuzzy constraints for a subset of SFM indicators obtained from the Canadian Council of Forest Ministers SFM Criteria. Input data is obtained through queries on aGIS database. The membership function for the fuzzy goals is based on performance against indicator targets and thresholds.

The forest development model is connected to a second sub-model formulated as a crisp LP for manufacturing optimization. Shadow prices on resource constraints from the crisp LP are used to guide the development model’s search for a global optimum. Harvest solutions from the development model are then passed to the manufacturing model for processing. The models continue iteratively until the shadow prices stabilize.

Results of a case study are shown to demonstrate use of the model in practice. The primary usefulness of the model is for developing scenarios and determining opportunity costs of SFM criteria for use in a stakeholder review process.
Hamish Marshall, Kevin Boston *

Oregon State University, Corvallis

“The potential for geographical information system logistic planning tools in the forestry industry”

For many years the forestry industry has utilized the data storage, analytical and data visualization power of geographical information systems (GIS). Many of the world's largest forestry companies have integrated GIS technology into their stand, inventory and harvesting planning systems. One area where the forestry industry has been slow to utilize the power of GIS is in the planning and management of their transportation systems. As the industry moves more towards customer driven supply chain management systems the level to which the industry manages their transportation system will need to increase. This paper looks at the potential of ESRI’s ArcLogistics software to solve modern log truck routing and scheduling problems.
David L. Martell

University of Toronto, Ontario

“The future of operations research in fire and fuels management”

Abstract forthcoming.
Marc McDill, Shawn Lehman

Pennsylvania State University, University Park

“Developing forest management plans for the Pennsylvania Bureau of Forestry”

Linear programming models were used to develop management plans for Pennsylvania’s 20 state forests. Management goals include identifying sustainable timber harvest levels, balancing age-class distributions, and maintaining areas of old forest. A key outcome has been better communication between administrators and field foresters, with field foresters gaining a better understanding of strategic concerns and administrators gaining a better understanding of operational constraints. Advisory boards consisting of representatives of both forest industry and environmental organizations have been strongly supportive. Public information meetings will be held in Summer 2003.
Public land agencies continually seek a better understanding of spatial and temporal changes to forested landscapes and to use this understanding in successive management decisions. TELSA (Tool for Exploratory Landscape Scenario Analysis) is a spatially explicit planning tool that simulates succession, natural disturbances, and management actions on a landscape over time. In 1994, the Northwest Forest Plan, developed a network of Late-Successional Reserves (LSR’s), with protecting and possibly improving late-successional habitat conditions the primary goal. One option in the LSR network strategy is using silviculture treatments to improve late-successional habitat conditions within young stands less than 80 years old. Although much debate still remains on the best treatments or stand-level designs to apply, thinnings can effectively influence species composition, stem growth, canopy complexity, and understory communities in residual stands. The Fall Creek Modeling Study, using TELSA, explores the connections between young stand management strategies and resulting landscape habitat patterns. The Fall Creek area is typical of areas with intense forest management of the past, fragmentation coupled with high road densities. While plenty of thinning opportunities exist in the analysis area, the Willamette National Forest does not expect to have sufficient funding or staffing to thin all available hectares over the next 50 years. This analysis evaluated a number of resource-driven management scenarios for selecting thinning prescriptions and prioritizing young stands for treatment. The analysis team used spatial mapping and stand simulation modeling tools to assess the effects of thinning treatments on LSR habitat patterns over a 200-year period. TELSA is a spatial modeling tool and PNW_GAP (originally ZELIG-PNW) is a stand growth simulator were used to apply thinning schedules to the landscape and project late-successional habitat development over a 200-year time period for each scenario. The TELSA spatial model was used to map stand attributes across the landscape at different time points for each scenario. TELSA model also tracked kilometers of road activated through management.
Participatory approaches to natural resource management and development have become widely accepted as the most effective instruments for achieving sustainable resource management particularly in the developing nations. Consequently, the literature is rich with management philosophies and paradigms supporting different types of participatory methods such as community-based resource management, joint forest management, co-management, adaptive management, participatory action research, and integrated resource management. While these methods are somewhat different in their overall approach, they have some fundamental similarities and commonalities in terms of their general process and the nature of issues and problems they are designed to address, which general include: multiple stakeholders and their multiple interests, plurality of perspectives, and the empowerment of stakeholders or communities so that they can actively participate in the planning and decision-making process.

This paper presents a participatory modeling framework that is consistent with participatory methods of assessing sustainable forest management. Under this participatory modeling framework, a number of techniques have been developed aimed at: 1) communicating the concept of sustainable forestry to local communities, 2) soliciting direct input and active participation of local communities in the planning and decision-making process, and 3) actively involve local stakeholders in the formulation of the models and in implementing the models for generating strategies and action plans. These models include: multi-criteria analysis, cognitive mapping, qualitative, and quantitative system dynamics. The models can be stand-alone models, or they can be combined together to constitute a more robust and flexible planning framework. These models have been applied to a number of case studies in the Philippines, Indonesia, Zimbabwe, and Ontario, Canada.
James Merzenich, Leonardo Frid, Sarah Beukema

USFS Pacific Northwest Region, Portland, Oregon

“Projecting landscape conditions in southern Utah using VDDT and TELSA”

The Vegetation Dynamics Development Tool (VDDT) is a state-transition modeling system that integrates the effects of succession and natural disturbances such as wildfire with management treatments. The Tool for Exploratory Landscape Scenario Analyses (TELSA) operates with VDDT to spatially model vegetative succession, natural disturbances, and management activities. Both tools are used to evaluate the response of non-spatial indicators to management actions. These indicators include age class distribution of the forest, the area or volume disturbed by a particular disturbance over time and others. In addition, TELSA tracks spatial indicators such as patch size metrics, and areas of interior and edge habitat.

This paper discusses the utility of using both these spatial and non-spatial models to project vegetative conditions and to evaluate alternative management strategies for the Beaver River drainage of southwestern Utah.
A series of timber inventory projections for the National Forest System were produced for the USDA Forest Service 2000 RPA Timber Assessment. This was the first time the aggregate timberland assessment system (ATLAS), was used for projections of inventory in the public ownership. Model revisions facilitated the simulation of large-scale disturbances associated with the mortality impacts of insects, disease, and fire. More recent updates have allowed us to extend the projection time horizon from 50 to 200 years. In this paper we will examine the effects of various levels of harvest and large-scale disturbance on the future inventory of our National Forests. We will describe the model and discuss the challenges associated with long-term projections.
The global forest sector model EFI-GTM was applied to assess regional impacts in Europe of potentially increasing timber supply in Asia and South America caused by forest plantations. The EFI-GTM is a multi-periodic partial equilibrium model, which contains 31 European regions and 30 regions for the rest of the world, and trade between the regions. The endogenous sectors include 26 forest industry products and 6 wood categories. Three alternative forest plantation scenarios were analysed: a base line assuming one percent annual rate of planting, high plantation scenario with gradually decelerating present planting rate and low supply scenarios corresponding to a pessimistic view on potential timber supply in Asia and South America.

High timber supply from plantations in Asia and South America results in lower harvest in Eastern Europe, and especially Russia with very limited impact on Western Europe. Increased timber supply from plantations will have very modest impact on paper & paperboard production, and more pronounced impact on pulp and wood products. Regional reallocation of pulp and woodworking industries caused by higher timber supply from plantation will lead to higher production increases in Asia and South America and lower in North America, Europe and considerably lower in Russia.

Increased supply from forest plantations will also have substantial impact on lowering timber and forest products prices globally and especially in plantation regions.
My objective is to examine the expected utility of general classes of forest growth models for forest management. Six classes of forest models are reviewed: Forest Yield Models; Ecological Gap Models (population succession); Ecological Compartment Models (resources fluxes); Process/Mechanistic Models; Vegetation Distribution Models; Hybrid Models. The review reveals structural shortcomings in several classes of models as potential tools for evaluating questions of sustainable forest management. For example, the great disadvantage of Forest Yield Models is that they are not linked to the underlying causes of productivity (the carbon and nutrient cycles, the moisture regime, and climate). Yield models implicitly assume that environmental conditions remain constant. This assumption is clearly unsuitable for evaluating climate change scenarios, which are crucial for long-term sustainability considerations. Hybrid models hold the greatest promise, because they are predicated on producing an operational process model with useful products on yield for the manager (e.g., PipeQual, Stand-BGC). The hybrid modelers base as much of their system on causal process models as is practical, and openly embrace relevant empirical results from yield models to complete the system.
Modern mechanized harvesters are often fitted with sensors that measure stem dimensions and with computers that optimally buck each stem to maximize the value gained based on stem dimensions, qualities, log prices and desired specifications. Optimally bucking individual stems, based on market prices, is unlikely to provide yields that meet order book constraints at the harvest unit or forest level.

The question becomes, if market prices and specifications do not yield volumes that meet these market and operational constraints, what set of prices and specifications will, and how does one find them given the fact that they will be continually changing as the harvesting operation moves through the forest?

An individual stem optimal bucking dynamic programming procedure was imbedded in a threshold accepting algorithm to adjust relative prices and minimum small end diameter specifications to meet order book constraints.

The adaptive control heuristic was tested on four stands where the location and detailed stem description of every tree was known. Three of the stands were virtual stands designed specifically to test the adaptive control heuristic. The fourth stand was a real-world stand.

This paper describes the adaptive control heuristic, presents results from a series of tests on its performance and compares the use of stem information collected during pre harvest inventory and by the harvester as it works its way through a harvest unit to calculate the relative prices that will best satisfy the market constraints. The heuristic has shown some promising and interesting results.
Contiguity is a vital property of spatial structure in landscape design, particularly forest and habitat reserve planning. While it is well recognized that contiguity represents the ability to travel from any point within a region to any other point within that region without leaving the region, it is typical that associated landscapes in this context, natural or planned, are not contiguous. As a result, the traditional notion of contiguity must be extended to account for relative degree of contiguity in fragmented landscapes. This paper proposes a measurement approach for assessing the relative degree of contiguity based on mathematical and spatial theories. Results are illustrate the advantages of this new approach compared to existing techniques. Further, this approach is integrated in a spatial optimization model to identify a management plan that maximizes landscape contiguity and minimizes land acquisition costs. Application results and computational experience are reported to highlight the usefulness of this approach for reserve design.
Real options is a means of valuing investment plans characterized by the following three components: (1) once acted upon, any single decision in the plan is irreversible, (2) the outcome of any decision is uncertain, conditional on a set or sets of random processes, and (3) decisions occur in a sequential fashion, where new insights and information can be incorporated into planning and decision-making as such items become available. Many forest management activities satisfy these three criteria.

Real options delivers an optimal set of rules that affect the probability and magnitude of future losses and gains by explicitly accounting for and reevaluating risk at each stage of execution. In contrast, traditional optimal control theory delivers an optimal set of activities. Optimal control is less flexible by assuming that management will not deviate from its plan over the horizon. This assumption can greatly exaggerate actual value and eliminate future pathways of higher net benefits.

This work explores how real options might improve forest management. The technique is specifically applied to the problem of wildfire management, where the timber and wildlife value of a forest is maximized over time. Results are compared with those from the more traditional optimal control approach. From these findings, directions for additional applications and opportunities for new algorithmic development are suggested.
Darek J. Nalle, Claire A. Montgomery, Jeffrey L. Arthur, Stephen Polasky

University of Nevada, Reno

“Evaluating gains from increasing model complexity in nature reserve design”

Efforts to interweave the modeling ability of Operations Research, Resource Economics, and Conservation Biology have resulted in much innovative work. Paralleling these efforts has been the advent of improved anthropogenic, biogenic, spatial, and temporal data and analysis tools. An anticipated outcome of these synergies is improved predictive ability that could illuminate strategies for more sustainable use and management of the natural resource base. However, improvements in data resolution and analysis are not without costs, and piecewise gains from the various components are not well understood. This work compares results from a range of models—with varying degrees of complexity and data requirements—for species conservation on a real landscape.
Silvana Ribeiro Nobre, Luiz Carlos E. Rodriguez *

Athena Management Systems for Natural Resources, Sao Paulo, Brazil

“A relational data model for the generation of large scale harvest scheduling and forest management problems”

In Brazil, several pulp and paper companies manage large tracks of land with forest plantations. The management of these forests demands integrated database management systems. One of the functions of these integrated databases is to provide organized information for linear programming harvest scheduling models. This paper suggests a data relational structure that facilitates the analysis, creation and storage of these models and results. Considering that users are not essentially experts in modeling and mathematical programming techniques, the relational model has to encapsulate complexities, to automate lots of calculations and to assume several consistency checks. Preferably these databases and matrix generators have to provide a friendly environment to parameterize the model generation process and to analyze the results. Advanced data modeling techniques were used to attend these goals. The data relational structure presented in this paper supports a forest decision support system developed in Brazil used by several pulp and paper companies which have diverse demands and very different management structures. The basic approach was to develop a flexible data model to satisfy very different information structures and frameworks. Basically, we describe: (i) the modeling techniques and required parameterization to represent the forest management regimes; (ii) the concept of “calculation batch” to encapsulate the mathematical programming routines; and (iii) the approach used to set together groups of parameters to define input data, different analysis scenarios and respective results. Finally, it is shown how the development of a tool that integrates data modeling and optimization techniques improved the adoption of non trivial forest planning techniques.
Silvana Ribeiro Nobre, Luiz Carlos E. Rodriguez *

Athena Management Systems for Natural Resources, Sao Paulo, Brazil

“Analysis and evaluation of the R-ratio heuristic”

The R-ratio heuristic (Rodriguez, 1994) solves large scale 0-1 integer programming versions of the Type I harvest scheduling problem (Johnson and Scheurman, 1977). This paper reviews its foundations and describes its evolution until now. Heuristic scheduling system patterns are used to represent the problem, to describe the evaluation function and to monitor the solution process. The analysis of its logic and elements is based on some artificial intelligence principles proposed to build heuristic processes. An AI approach based on intelligent agents provides the basis to analyze the R-ratio’s (i) escape strategy from local optimums; (ii) its hybrid A*-greedy strategy to the solution search; and (iii) how much it differs from other three heuristics (tabu search, simulates annealing and genetic algorithms). AI concepts are also utilized to evaluate performance indicators of *efficacy*, measured by the proximity to the optimal solution of the non-integer linear programming version of the same problem, and *efficiency*, measured by penetrancy and space complexity. For the test problems, the R-ratio strategy to escape from local optimums proved efficacious given that several feasible solutions with objective function values below the range of 0.5% were obtained. And the R-ratio approach to find feasible solutions also proved efficient given its focus on a low cost strategy to select path searches.
Kenneth Olofsson, Jonas Bohlin, Tomas Lämås, Håkan Olsson

Swedish University of Agricultural Sciences, Umeå

“Estimation of forest stand parameters using remote sensing single tree detection and field plots with tree positions”

The method for single tree detection in high resolution (pixel size 0.3 m – 1 m) digital imagery, originally developed by Richard Pollock of Canada, has been tested for Scandinavian conditions and further developed. The method uses a library of tree templates, which are projected with correct view-angle and illumination in the different parts of an image. The library of projected tree templates is then correlated to each potential tree position in the digital images, and the most likely template is chosen for each point with a high correlation. This method will find most, but not all, trees. In addition, image parameters such as crown shape and tree position are directly estimated. In order to combine the image parameters with field data, a method for rendering templates of whole field plots (with radius about 10 m), is under development. This method will utilise a quick field method for measuring the tree positions on field plots. The tree patterns for the field plots are then correlated with the tree patterns in the imagery, and guided by an approximate GPS co-ordinate, we hope to find the correct location in the image for each field plot. We can then relate the vector of field- surveyed forest parameters to the vector of image-derived features for the same plot. The most immediate gains with this method is that we can derive estimates of parameters such as stem number and stem volume for all trees in the stand, in addition to tree maps for the dominating trees.
Leif Olsson

Mid Sweden University, Sundsvall

“Optimal road investments – a forest company case study”

A joint project between the Swedish forest company Holmen Skog and Mid Sweden University was initiated in October 2000. The Kempe foundation and Gunnar Sundblads research found finance the project. The first part of the project was to develop optimization models for selection of gravel roads for upgrading to highest road standard, during a ten year planning horizon. Since then, several mixed-integer linear models have been tested at one of Holmen Skogs forest districts in Sweden. Results from this case study show that the problem can be solved in a few minutes with our best model formulation, commercial software and a standard PC. Rapidly available solutions give the decision maker the opportunity to rerun the optimization several times, to handle low quality data and uncertain weather events. Furthermore, calculate the total, marginal and average cost of different road upgrading policies, in reasonable time. A model that is easy to understand, implement and use have been the core issue of the project. Further research, supported by this work, will be carried out by the Forestry Research Institute of Sweden and turned into a decision support system prototype during 2004. The data supply will, in that case, be partly from the Swedish National Road Database.
Myrna Palmgren, Mikael Rönnqvist

Linköping University, Sweden

“RuttOpt – an operative transportation planning system”

The forest industry represents a major part of the demand for transportation of goods in Sweden. Transportation related to the forest industry constitutes approximately 25 percent of all domestic transport by truck and railway. The costs of transportation represent one third of the total cost of raw material, round wood, to the forest industry. An efficient use of transportation is vital to the competitiveness and environmental influence of the forest industry. A practical and efficient transportation planning is an important part of the overall wood chain. There are many possibilities for this planning ranging from monthly flow planning, weekly and daily route planning down to real time dispatching. We describe a transportation system called RuttOpt which consists of a database with all required information regarding e.g. supply, demand and trucks. Connected is also the new Swedish road database that consists of information about all roads in Sweden. With this system we can easily find distances and illustrate routes on a mapping module. An important part of the RuttOpt system is a set of optimization modules that is used to find optimal or near optimal routes for the entire fleet of trucks. The models are based on set partitioning models and solution methods include column generation, branch and price with constraint branching. The solution methods are capable of solving the integer programming within practical time limits. We solve both daily and weekly planning problems. Numerical tests from a set of major Swedish forest and transportation companies are provided.
Timber price reports for the southeastern United States show great volatility. In Louisiana, from 1955 to 2002, prices for pine sawtimber changed annually from –34% to +61%; during the same period, pine pulpwood prices changed from –40% to +36%. While over long periods of time stumpage prices have tracked steadily upward, 6.5% and 4.6% per year for pine sawtimber and pulpwood, respectively, it has been argued that optimal financial timber management depends more on timing harvests with price increases than on sound biological production of volume. Forward-recursive dynamic programming was employed to determine optimal financial management regimes under stochastic prices. These regimes were compared to management regimes found using deterministic price projections to identify characteristics, particularly age within a rotation, under which “playing the market” decisions were superior to following a prescribed silvicultural regime.
Timber harvesting is analyzed allowing both stochastic volatilities and deterministic functions in stumpage prices as well as deterministic models and risk in timber growth, and additionally variable silvicultural costs. All economic and risk parameters, as well as models and functions, have been established and estimated by the national forest inventory (NFI) and the price and cost statistics of the Forest Statistics Information Service (FSIS).

Growth models are as provided by one five-year steps of the MOTTI software. For interpolations, locally calibrated growth models and a logistic growth model have been employed. The stumpage price drift and volatility rates have been estimated using real price data from 1950-2002. The reforestation cost function is based on the real costs during the period 1977-2002. The growth risk comes from mensuration publications.

Empirical studies suggest that forest owners' utility is risk neutral or risk averse. Solutions have been provided for risk neutral (linear) and the logarithmic utility, the latter being asymptotically superior to any other strategy.

Both stumpage price and growth risks are proxied by the geometric Brownian motion (GBM). The key notion of the study is the development and implementation of new solutions, and the testing of these solutions numerically in day-to-day decision-making situations in order to provide new features for software such as MOTTI. The results have been examined with respect to the Forest Act and silvicultural recommendations.
Peter Rauch

BOKU – University of Natural Resources and Applied Life Sciences, Wien, Austria

“Estimating the harvesting potential for high mechanized harvesting systems in small scale forestry with a GIS model”

In Austria woodlot owner co-operatives bundle the supply from round wood coming out of the small forest plots. The only information the manager of a woodlot owner co-operative actually has are some personal data from his members and the size of their forest because there exit no forest management data at all.

There is an increasing demand of the wood industry for small timber in Austria. On the one hand exists a large green stock, but on the other hand the continuous supply – especially out of the numerous small forest plots - is a problem. The Austrian Forest Inventory shows tending arrears with a harvesting potential of 40,5 million m$^3$ for Austrians small forests.

So for a woodlot owner co-operative with 240 members representing 9,000 ha of forest land a basic information system has been set up using digital land register maps as well as digital land register data and stereoscopic aerial view interpretations. These data are required as basic input for the harvesting model.

To estimate the harvesting potential for high mechanised harvesting systems a model prototype has been created using Arc View 3.2a and Model Builder 1.0a from ESRI. The prototyping of the model has been done for a tracked harvester. For a given soil condition scenario the model estimates areas where machinability of the stand and trafficability of the terrain both are fitting to the harvester configuration. Validations of the model results show that the estimated trafficability matches the reality of the mountainous research area quite well.
Rui Pedro Ribeiro, José G. Borges *, Vanda C. Oliveira

Universidade Técnica de Lisboa, Portugal

“Developing information systems for Mediterranean forest ecosystem management”

Mediterranean forest ecosystems are generally characterized by abundant biological diversity and by a fragility that derives from a harsh climate and difficult socio-economic conditions. The consequent complexity of Mediterranean forest ecosystem management points to the urgency of both promoting interdisciplinary research and organizing Mediterranean natural resources data. Research in Ecology, Economics and other pertinent subject areas is expanding at an ever-increasing speed. Yet this expansion of research may lead to a waste of resources if data is not modeled such that information is adequately organized and distributed. This paper presents preliminary results from research aiming at developing information systems for Mediterranean forest ecosystem management. Specific challenges to be addressed include the linkage of plant, animal and economic spatial and aspatial data, the development of a data quality framework and the design of a decision support system architecture. Preliminary results of the application of the proposed strategy to Mediterranean ecosystems that encompass an area of circa 50 814 ha are presented. Extensions to this study are identified.
Stephanie Snyder, Charles ReVelle, Robert Haight

North Central Research Station, St. Paul, Minnesota

“One and two objective approaches to an area-constrained habitat reserve site selection problem”

We compare and contrast several different ways to model a habitat reserve site selection problem in which a limit on the total area selected is required. Classic maximal covering and location set covering problems typically include a constraint on the number of sites that can be selected. If potential habitat sites vary in terms of area or acquisition cost, then sites need to be differentiated by these characteristics in the selection process. The simple constraint on the number of selected sites must then be replaced by one limiting the total area or cost of the sites. We show that average solution time improves considerably when an area-constrained, maximal covering habitat selection model is modeled as a two objective problem as opposed to a single objective problem in which a straight-forward constraint on the maximum allowable area selected is employed. Computational experience is reported using a large dataset from Australia.
Daniel Spring

Monash University, Melbourne, Australia

“One optimal conservation of neotropical wildlife”

The loss of primary tropical forest through timber harvesting and land clearing for agriculture is a major cause of global biodiversity loss. There is growing recognition of the need to conserve such forest by placing it in conservation reserves. In many countries, the rate of forest loss has been high and in some cases, accelerating. However, there is some uncertainty about where and when future forest loss will occur. Stochastic dynamic programming has been used to solve example problems that account for this uncertainty as well as accounting for limitations on the resources available for purchasing land to include in conservation reserves. We extend these methods and apply them to a case study focusing on the problem of selecting sites in a neotropical country to achieve a goal of maximizing species coverage by the end of the planning horizon.
Forest management is increasingly in need of GIS-based planning tools for developing projects that are both economically efficient and environmentally beneficial. Timber harvest in particular is often planned without in-depth analysis of scheduling alternatives that might improve efficiency and environmental effects, leaving managers vulnerable to criticism about data and information used to develop projects. With increased pressure on public land managers to provide economic and ecological justification for harvest projects, the use of analysis tools has become critical for efficient planning.

MAGIS eXpress is a modeling system for spatially-explicit analysis of timber harvest scheduling and access management. GIS layers are imported and used as the basis for formulating harvest and access problems. Access problems that can be addressed include new road construction, existing road reconstruction, and road decommissioning. Vegetation growth (and timber volumes) are modeled based on ‘vegetative pathway’ principles. Data are viewed, scenarios are developed, and results analyzed using state-of-the-art ArcGIS map input screens. A MAGIS eXpress solution includes the schedule of harvest activities, present net value(s), individual predicted values by treatment unit, and the predicted vegetation distribution, including standing volume (residual volumes). A sample problem is presented to illustrate MAGIS eXpress uses and features.
This study combines timber production and environmental values, applying a dynamic forest level economic model with any number of forest age classes. The model includes endogenous timber price, nonlinear utility or nonlinear harvesting costs and various possibilities to specify the dependence of environmental values (related e.g. to species persistence) on the forest age class structure. The nonlinearities in the net benefits from timber production have the consequence that fluctuations in optimal timber harvesting may totally vanish or at least become smaller than in forest scheduling models without \{ad hoc\} even flow constraints. If environmental values are specified to depend on the fraction of forest land preserved as old growth, the optimal long run allocation between timber production and old growth is represented by an equilibrium continuum. Thus the optimal long run allocation depends on the initial age class distribution. The continuum and the dependence of initial age class distribution vanish when the rate of discount approaches zero. If the environmental value increases smoothly with stand age, the long run equilibrium may simultaneously include multiple rotation periods. The model determines whether producing timber and producing environmental values is optimal to carry out separately at different parts of the forest or over the whole forest land by applying extended rotation. Numerical computation suggests that the optimal solution always converges toward some optimal long run stationary age class distribution.
Magnus Thor

The Forest Research Institute of Sweden, Uppsala

“Modeling infection and spread of Heterobasidion annosum in coniferous forests in Europe”

The pathogen Heterobasidion annosum (Fr.) Bref. causes severe problems for forestry throughout the northern temperate zone, infecting mainly coniferous trees. Damages occur as decayed wood on spruce and fir, and death on young pines. Annual losses on a European level are estimated to €790 million. The infection biology of the fungus is well described, although the variation is considerable. This paper will describe two modeling projects in Europe. The first, MOHIEF (Modeling of Heterobasidion infection in European forests), is a concerted action within the EU aiming at a decision support tool for forest managers as well as a tool for researchers throughout Europe. MOHIEF takes into account various tree species over a range of forest conditions, and is solely intended to model infection and spread of the pathogen. The other project, Heureka, is aiming at a national (Swedish) system for forest planning on strategic, tactical and operative levels. Although being national, the system shall be possible to use in regional and even local applications. In Heureka the impact of Heterobasidion is one among other components to be modeled, such as growth and yield, wood properties, biodiversity, biomass-carbon relationships and forest-owner behavior.

Simulations of Heterobasidion infection will be demonstrated in conjunction with examples of how the models can be exploited, from a forest manager’s and a researcher’s perspective.
Sándor F. Tóth, Marc E. McDill *, Stephanie Rebain

Pennsylvania State University, University Park

“Exploring the efficient frontier of a bi-criteria, spatially explicit, harvest scheduling problem”

When criteria conflict with one another, such as maximizing both the net present value and the minimum mature patch size of a forest, the efficient frontier helps the decision maker identify the best compromise solution. We tested and compared four approaches of mapping this “trade-off” curve on a hypothetical forest of 50 stands: (1) the constraining method, (2) the weighted objective function method ($P_\lambda$), (3) the decomposition method based on the Tchebycheff Norm ($P_\beta$), and (4) the compromise programming method. We concluded that while the constraining method is capable of identifying all efficient points at a relatively high computational cost, $P_\lambda$ and $P_\beta$ methods find many of the solutions fast. Combined approaches were also considered.
James A. Turner, Joseph Buongiorno *  

University of Wisconsin – Madison  

“Estimating price and income elasticities of demand for forest product imports from pooled cross-section and time-series data”  

Static and dynamic models of the derived demand for forest product imports were estimated for each of ten major forest products covering industrial roundwood, woodbased panels, pulp, and paper and paperboard. The models were estimated with panel data from 64 countries for 1970 to 1987, and with the pooled ordinary least squares method, first-differencing, fixed effects, random effects, and the Arellano-Bond approach. The predictive accuracy of the demand equations was tested with post-sample data from 1987 to 1997. Based on multiple criteria, the best results obtained with the static model estimated by first differencing, followed closely by the dynamic model estimated by the Arellano-Bond method or first differencing.
Jussi Uusivuori, Jari Kuuluvainen
University of Helsinki, Finland

“The harvesting decisions when a standing forest with multiple age-classes has value”

A solution is demonstrated to an infinite-horizon, discrete-time utility model describing the behavior of a nonindustrial private landowner who is managing a multiple age-class forest and who values both consumption derived from harvesting the trees and amenity derived from the standing trees. The model is a discrete-time generalization of the Hartman model of optimal harvesting. The paper derives a simple policy rule to attain a normal forest from any initial age-class distribution and demonstrates how a non-cyclical forest allowing a constant periodic harvest is typically not a normal forest. This means that an even-flow timber harvesting is not tied to the existence of a normal forest structure. In the numerical analysis it is illustrated, for example, how the subjective time-preference rate affects the optimal path of timber harvests and the state of the equilibrium forest.
Area-based harvest scheduling models, where management decisions are made for relatively small units subject to a maximum harvest area restriction, are known to be very difficult to solve by exact techniques. Previous research has developed good approaches for solving small and medium sized forestry applications based on projecting the problem onto a cluster graph for which cliques can be applied. However, as multiple time periods become of interest, current approaches encounter difficulties preventing successful identification of optimal solutions. In this paper we present an approach for elastizacing timber demand constraints, which lends itself to an efficient solution technique. It is also possible using this approach to examine trade-offs between objective value performance and maintaining demand constraints.
Interactions of forest structure and spatial restrictions on goal achievement

Spatial forest planning literature generally focuses on modeling adjacency constraints and/or harvest opening size limits. Findings have indicated substantial costs associated with spatial constraints, and this has spawned a great deal of work on model formulations and heuristics to minimize these costs. A notable feature of this body of work is how variable the costs may be: in some situations, the cost of spatial constraints is only a few percent; in others, as high as 30% or more. Clearly, much of this variability is due to the constraints applied (width of green-up buffers, length of green-up interval, size of opening), but it is has been conjectured that forest structure itself can be a large determinant of the costs associated with spatial restrictions (Walters & Cox, 2001). In some forests, a given spatial restriction may have very little impact, but in others it may be severely limiting. This paper explores the relationship between different forest structures and commonly applied spatial restrictions in an attempt to quantify the costs of spatial restrictions associated with various forest structures.

To explore the effects of forest structures on goal achievement under spatial constraints, eight fully regulated forests of 32,000 ha were devised, differing only in the spatial distribution of stands across various square and hexagonal grids. In the absence of spatial constraints, a single strategic harvest-scheduling model can be constructed to serve all these different forests. When spatial restrictions are considered in a tactical planning exercise, significant reductions in achievable harvest volume and/or present net value were found, with some forest structures exhibiting much greater than others under a given set of spatial restrictions. In many cases, incorporating spatial analysis into the strategic planning model could mitigate the shortfalls between strategic and tactical schedules.
Planning an effective and efficient initial attack wildfire suppression organization in preparation for an uncertain fire season is a challenging task for fire planners. This paper describes features of the Wildfire Initial Response Assessment System (WIRAS), a discrete-event stochastic simulation model, which can assist fire planners in wildfire preparedness planning and policy analysis. WIRAS simulates, according to user-defined rules, all phases of local initial attack resource management and movement to meet the service needs posed by a varying fire workload over the landscape and through time. Planners can evaluate the performance of alternative preparedness organizations against either historic or potential fire seasons. In addition to national and regional scale planning capability, WIRAS allows planners to evaluate local preparedness organizations within a larger geographic fire environment to take better account of competition for externally shared suppression resources, like airtankers, helitack, and smokejumpers.
Andrew Wilson, Marc Wiitala

Riverside Fire Lab, Portland, Oregon

“An empirically based model for estimating wildfire suppression resource response times”

Suppression resource response times are an important component in planning models used to evaluate the effectiveness of wildfire preparedness organizations. Most fire planning models rely on subjective estimates of travel times between predetermined points on the landscape. This paper describes the system underlying a raster-based travel time model that will provide greater accuracy, objectivity, and flexibility in estimating travel times between any points on the landscape. The methodology integrates empirically collected data using GPS and existing GIS data to create the travel time prediction model.
Nearly 33% of the U.S. is forested, providing important ecosystem services such as sequestration of CO2. Estimates of carbon stocks and fluxes in forest ecosystems and wood products are required for national greenhouse gas inventories under the United Nations Framework Convention on Climate Change. Although the U.S. has not ratified the Kyoto Protocol, there is interest in the U.S. and elsewhere in managing forest ecosystems to sequester carbon to slow the accumulation of CO2 in the atmosphere. To meet these needs, we estimate historical, present, and future carbon stocks and fluxes in U.S. forests. Forest inventory data supplemented with data from intensive research sites and models are used to estimate carbon stocks in above- and belowground live tree, standing dead tree, down dead wood, forest floor, and soil. Historically, reversion of cropland to forests has increased carbon storage in biomass and soils. During 2001, net annual carbon sequestration in forests was estimated to be 149 Tg C, and that in wood products and landfills an additional 58 Tg C. This net sequestration offset approximately 13% of total U.S. CO2 emissions. Net annual carbon sequestration in forests declined by 22% between 1990 and 2001, due mostly to decreased sequestration in soil. Management activities and ongoing impacts of previous land-use changes are major influences on current and future estimates of net carbon flux.
July 26, 2001 Skamania Lodge, Stevenson, Washington Columbia River Gorge Pacific Northwest United States. The symposium will be held as a satellite meeting, in conjunction with a week-long international meeting of the International Union of Forestry Research Organizations (IUFRO), section on Molecular Biology of Forest Trees. It will feature a number of speakers from outside forestry who will discuss: Â— What is known of the molecular nature of the domestication process in agricultural crop breeding, Â— What ecophysiological, morphological, developmental, and chemical targets are desirable for dom The Skamania Lodge is 44 miles east of Portland off I-84 in Stevenson, on the Washington side of the Columbia River Gorge. The lodge is only moments from many recreational activities and attractions, including beautiful hiking trails, more than 70 waterfalls, whitewater rafting, boat cruises and wine tours. Portland International Airport is 42 miles away. 1131 Sw Skamania Lodge Way. Stevenson, Washington. 98648, United States. Hotel Amenities. Skamania Lodge is a beautiful hotel on an 18 hole golf course in the Washington side of the Columbia Gorge less than an hour from Portland airport. Dinner in best restaurant is excellent especially the wild mushroom appetizer. We are patrons of some of the better steak houses in the USA which include The Steakhouse at Harrahs in Reno and Besh Steakhouse in New Orleans. Â— Dear Maimmi, We sure appreciate the wonderful review. I’m glad we were able to assist during the forest fire on the Oregon side of the river. I know our team worked extremely hard during this event helping displaced residents as well as assisting the Red Cross and I’m very happy to hear that we were able to take such good care of you. We hope to see you again very soon.