Contents

- Trends in Forest Management Planning
- Forest Transportation Planning Tools
Management objectives

**Economic goal**
- Minimizing costs
- Maximizing net present value

**Environmental concerns**
- Minimizing costs
- Minimizing environmental impacts

**Social aspects**
- Minimizing costs
- Maximizing social benefits
Trends in Forest Management Planning

- Changes in planning problem size

Strategic planning at landscape level without spatial considerations

Tactical planning at forest stand level with limited spatial considerations

Spatial approach to Strategic Forest Planning (Tactical planning at landscape level)

- Spatial constraints
- Geographic Information Systems
- Remote sensing
- Computer capacity
Forest Transportation Planning Tools

- Transportation Routing Problems
  - Multiple timber sale locations
  - Multiple routing options
  - Multiple destinations
  - Multiple time periods
Mica Creek watershed

Network representation of the Mica Creek road system

Estimated sediment yields (ton/year/segment) by WEPP

Running WEPP batch from NETWORK2000

User-defined environmental cost

\[ \text{Min} \sum_{i=1}^{L} [(\text{var\_cost}_i \times \text{vol}_i) + (\text{fixed\_cost}_i \times B_i) + (\text{weight} \times \text{Sediment}_i)] \]

Environmentally Sound and Economically Efficient Road Systems
### Alternatives

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Weight</th>
<th>Hauling Costs (Millions)</th>
<th>Construction Costs ($1,000)</th>
<th>Total Network Cost ($ Millions)</th>
<th>Total Road Length (km)</th>
<th>Total Sediment Delivered to Streams (tons)</th>
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<tbody>
<tr>
<td>1</td>
<td>NONE</td>
<td>17.9</td>
<td>841.6</td>
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<td>853.3</td>
<td>19.5</td>
<td>375.8</td>
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<td>$100 / lb.</td>
<td>18.7</td>
<td>853.3</td>
<td>19.6</td>
<td>377.9</td>
<td>30.2</td>
</tr>
</tbody>
</table>
Minimize \[ \sum_{i=1}^{e} \left[ (\text{var\_cost}_i \times \text{vol}_i) + (\text{fixed\_cost}_i \times B_i) \right] \]

Subject to \[ \sum_{i=1}^{e} (\text{sediment}_i \times B_i) \leq \text{allowable\_sed} \]

\text{var\_cost}_i \quad : \text{variable cost for edge } i \ (\$/\text{vol})
\text{fixed\_cost}_i \quad : \text{fixed cost for edge } i \ ($)
\text{sediment}_i \quad : \text{sediment amount eroding from edge } i \ (\text{tons})
\text{vol}_i \quad : \text{total volume transported over edge } i
B_i \quad : \text{binary variable (1 if edge is used, 0 otherwise)}
e \quad : \text{total number of edges in the road network}
\text{allowable\_sed} \quad : \text{sediment restriction (tons)}
Forest Transportation Planning Tools

Ant Colony Metaheuristic Optimization
Forest Transportation Planning Tools

- MIP vs. Ant Colony
Forest Transportation Planning Tools

100 Links - Cost minimization subject to sediment < 550 tons

ACO-FTPP

Variable cost: 102,510 ($26.64/vol)
Fixed cost: 48,780 ($12.67/vol)
Total cost: 151,290 ($39.31/vol)
Total sediment: 541.93 tons

MIP solver

Variable cost: 102,510 ($26.64/vol)
Fixed cost: 48,780 ($12.67/vol)
Total cost: 151,290 ($39.31/vol)
Total sediment: 541.93 tons
Forest Transportation Planning Tools

- **200 Links - Cost minimization subject to sediment < 1000 tons**

**ACO-FTPP**

- Variable cost: $307,145 ($30.43/vol)
- Fixed cost: $69,281 ($6.86/vol)
- Total cost: $376,426 ($37.29/vol)
- Total sediment: 998.20 tons

**MIP solver**

- Variable cost: $271,486 ($26.90/vol)
- Fixed cost: $83,936 ($8.31/vol)
- Total cost: $355,422 ($35.21/vol)
- Total sediment: 957.57 tons
300 Links - Cost minimization subject to sediment < 1000 tons

**ACO-FTPP**
- Variable cost: 622,803 ($37.29/vol)
- Fixed cost: 139,876 ($8.38/vol)
- Total cost: 762,679 ($45.67/vol)
- Total sediment: 989.69 tons

**MIP solver**
- Variable cost: 594,918 ($35.63/vol)
- Fixed cost: 117,391 ($7.02/vol)
- Total cost: 712,309 ($42.65/vol)
- Total sediment: 973.84 tons
## MIP vs. Ant Colony (Computation time)

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<th>Case</th>
<th>Hypothetical Transportation Problems</th>
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Fuel Treatment Management
FIRE-MAGIS

- Optimizing Spatial and Temporal Treatments to Maintain Effective Fire and Non-fire Fuels Treatments at Landscape Scales
  - Determines when to treat, where to treat and how to treat in order to maximize the effects of fire hazard reduction under a given budget
FIRE-MAGIS

FFE-FVS
Alternative fuel treatment schedules
Changes in fuel characteristics in each stand over time

MAGIS
Long-term fuel management decisions

FlamMap
Fire behavior characteristics in each period
Fuel maps across a landscape in each time period

Each forest stand
5 time periods
5 different treatments

(www.fire.org)
Concluding Remarks

- As better and more precise data are developed, forest planning problems become larger and more complex due to multiple objectives and constraints that need to be considered.

- Contemporary forest management planning requires more efficient problem-solving techniques as well as large computation capacity.
Forest Management Planning Tools

- Forest Transportation Planning
- Management Activity Planning
Forest Planning Tools - MAGIS

- MAGIS: Multi-resource Analysis and Geographic Information System

- MAGIS is a microcomputer-based spatial decision support system that simultaneously schedules forest resource management and road activities on both a geographic and temporal basis.
Forest Planning Tools - MAGIS

- MIP solver
  - Limited to small size problems
  - A commercial LP package is required

NEW!

Heuristic Solver for MAGIS

- Simulated Annealing for Harvest Scheduling
- Network Algorithm for Access Road Planning
Forest Planning Tools - MAGIS

- **Upper Belt Project Area (Lewis and Clark National Forest in Montana)**
Problem descriptions
- 47,000 acres (19,000 ha.)
- 999 polygons
- 21,147 management options
- 926 road links
- Two output products (sawtimber and pulpwood)
Management Activity Planning
Tools

- MAGIS
- FIRE-MAGIS
Each forest stand
5 time periods
5 different treatments

FFE-FVS

Alternative fuel treatment schedules
Changes in fuel characteristics in each stand over time

MAGIS
Long-term fuel management decisions

Fire behavior characteristics in each period
Fuel maps across a landscape in each time period

FlamMap

(www.fire.org)
Invasive Weeds Management
Invasive Weeds Management

Decision Support System

- Spatial Data
  - Weed species
  - Weed locations
  - Vegetation
  - Forest plans

- Susceptibility
- Spread rates
- Treatments
  - Types
  - Efficacy
  - Costs

Priority
Objective
Constraints

Optimal resource allocation
What-if and trade-off analyses
Invasive Weeds Management

Current

Future

1\textsuperscript{st} Period

3\textsuperscript{rd} Period

susceptible

unsusceptible

Without treatment

With treatment

Infested area

Newly infested area
Invasive Weeds Management

Create alternative weed treatment patterns and schedules

Simulated Annealing (SA) iterative optimization

Evaluate alternative treatment patterns and schedules

Find the optimal treatment location, timing, species to minimize total infested acres over planning periods

Spread rates
Susceptibility

Treatment costs and efficacy

Resource constraints

Priority and weights
Trends in Forest Management Planning

- Changes in problem-solving techniques

Economic goal without spatial considerations
  - Linear Programming

Economic efficiency

Environmental concerns

Social aspects

Spatial issues
  - Mixed-Integer Programming
  - Heuristic optimizations
  - Spatial decision-making
**NETWORK 2000 – Input data**

### Link Data

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<tr>
<th>Link</th>
<th>From node label</th>
<th>To node label</th>
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- **Variable costs**: ( $1/m³, $10,000 )
- **Fixed costs**: ( $1/m³, $10,000 )

1. Variable costs
2. Fixed costs
NETWORK 2000 – Input data

Sale Data

<table>
<thead>
<tr>
<th>Line</th>
<th>Entry node</th>
<th>Destination node</th>
<th>Timber volume (units)</th>
<th>Harvest year</th>
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<td>SuperMill</td>
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<td>SuperMill</td>
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Heuristic Network Algorithm

- Combining the Shortest Path Algorithm with heuristic approaches

- Redefining the variable cost by converting the fixed cost into equivalent variable cost

\[ VC_i = VC_{INIT_i} + \frac{FC_i}{\sum Vol_i} \]