Optimization Techniques for Natural Resources

SEFS 540 / ESRM 490 B

Lecture 1 (3/27/2017)
About the Instructor

• **Teaching**: inspire students to be curious but critical learners who can think for themselves and nurture creative ideas

• **Research**: quantify resource tradeoffs and production possibilities to aid natural resource management decision

• **Training**: forest engineering, operations research and forest management science
The decision making process in natural resources management

Data collection
- Remote Sensing
- Field Surveys
- Permanent Plots
- Questionnaires

Data processing

Decision tools to generate management alternatives
- Optimization
- Simulation
- Economics
- Finance

Demonstration/visualization of alternatives & tradeoffs

Consensus Building
- Delphi-process
- Nominal Group Technique

Consensus Building

Monitoring

Implementation

Natural Science                   Management Science               Social science
Models to Solve Natural Resource Problems

• **Descriptive models**
  – What’s there? – patterns
  – What’s happening? – processes
  – Spatial and temporal interactions
  – Measurements, monitoring
  – Statistical models
Models to Solve Natural Resource Problems (cont.)

• Predictive models
  – What happens if we do this vs. that?
  – Simulation, stochastic model, scenario analyses, etc.

• Prescriptive models
  – What is the best course of action?
  – Optimization
How do descriptive, predictive and prescriptive models work together?

- **Descriptions**
  - Where are the insects?
  - Where are the damaged trees?
  - Intensity of damages
  - Host selection behavior
  - Population dynamics
  - Stand susceptibility and risk

- **Predictions**
  - Projected spatial dispersal
  - Expected insect and host response to treatments

- **Prescriptions**

Image source: Mark McGregor, USDA Forest Service, Bugwood.org
The role of decision models
Models and Model Building Fundamentals
Models

- Abstract representations of the real world
- Lack insignificant details
- Can help better understand the key relations in the system/problem
- Useful for forecasting and decision making
Model types

- Scale models (e.g., model airplane)
- Pictorial models (photographs, maps)
- Flow charts: illustrate the interrelationships among components
- Mathematical models
1. **Decision variables**: 

Let \( x_i \) (where \( i = a, b, c, d \) or \( e \)) denote the decision whether stand \( i \) should be cut or not.

\[ x_i = 1 \text{ if stand } i \text{ is to be cut, and } x_i = 0 \text{ otherwise; } x_i \in \{0, 1\}. \]

2. **Objective**: 

Let \( c_i \) denote the financial return from cutting stand \( i \).

\[
\text{Max } Z = c_a x_a + c_b x_b + c_c x_c + c_d x_d + c_e x_e + c_f x_f = \\
= \sum_{i \in N} c_i x_i, \text{ where } N = \{a, b, c, d, e, f\}
\]
3. Constraints:
Adjacent stands are not allowed to be cut.

\[
\begin{align*}
\text{Max } Z &= \sum_{i \in N} c_i x_i \\
\text{subject to: } & \\
x_a + x_e &\leq 1 \\
x_a + x_d &\leq 1 \\
x_b + x_c &\leq 1 \\
x_b + x_d &\leq 1 \\
x_b + x_e &\leq 1 \\
x_c + x_d &\leq 1 \\
x_c + x_e &\leq 1 \\
x_d + x_f &\leq 1 \\
x_b + x_c + x_d &\leq 1 \\
x_b + x_c + x_e &\leq 1 \\
\end{align*}
\]
A mathematical program:

Max $Z = \sum_{i \in N} c_i x_i$

subject to:

\[ x_a + x_e \leq 1 \]
\[ x_a + x_d \leq 1 \]
\[ x_b + x_c + x_d \leq 1 \]
\[ x_b + x_c + x_e \leq 1 \]
\[ x_d + x_f \leq 1 \]
\[ x_i \in \{0, 1\} \]
Mathematical models

• The most abstract
• Concise
• Can be solved by efficient algorithms using electronic computers,
• Thus, very powerful.
Good Modeling Practices

• The quality of input data determines the quality of output data
• The nature of the management problem determines the choice of the model (not the other way around)

Ask:
• Is the model to be used to simulate, evaluate, optimize, or describe the system or phenomenon?
Good Modeling Practices (cont.)

• What is the scale, resolution and extent of the problem?
• What are the outputs (results) of the model?
• What are these results used for?
• Who will use them?
Optimization Models

- Deterministic vs. probabilistic optimization
- Convex vs. non-convex problems
- Constrained vs. unconstrained optimization
- Exact vs. ad-hoc (heuristic) optimization
- Static vs. sequential (dynamic) decisions
- Single vs. multi-objective optimization
- Single vs. multiple decision makers
- Single vs. multiple players (games)