Optimization Techniques for Natural Resources

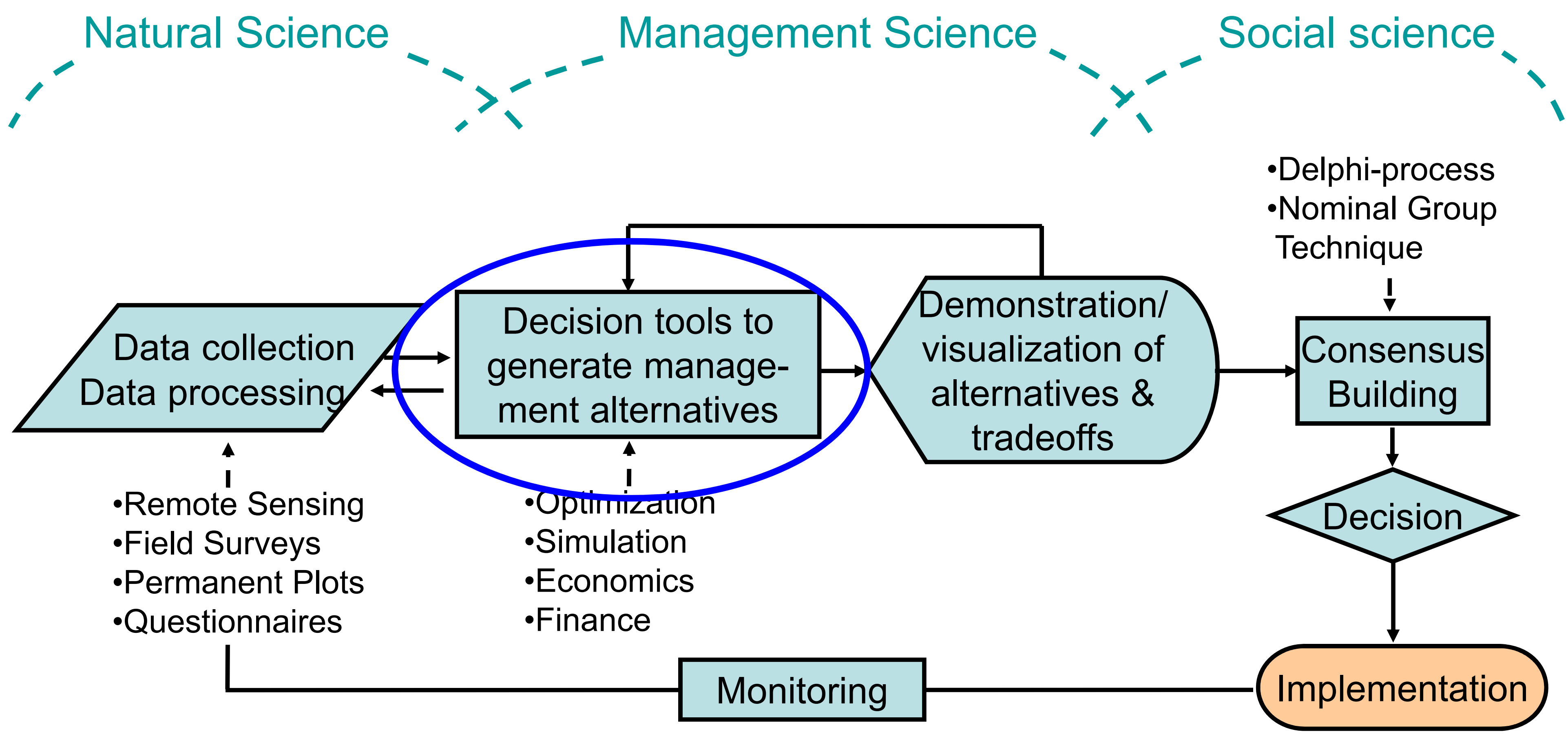
SEFS 540 / ESRM 490 B

Lecture 1 (3/27/2017)

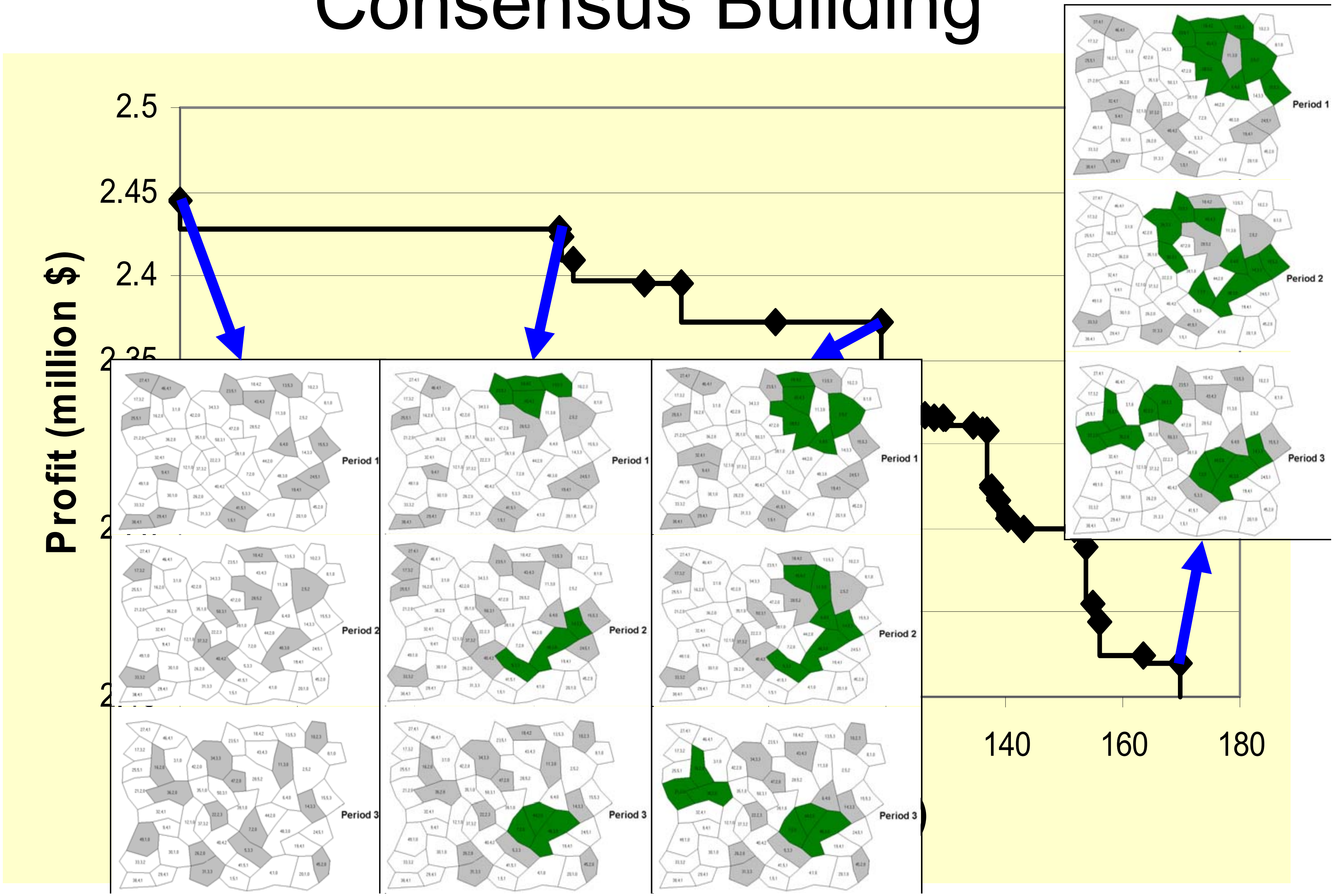
About the Instructor

- 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



Management Alternatives and Consensus Building



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?

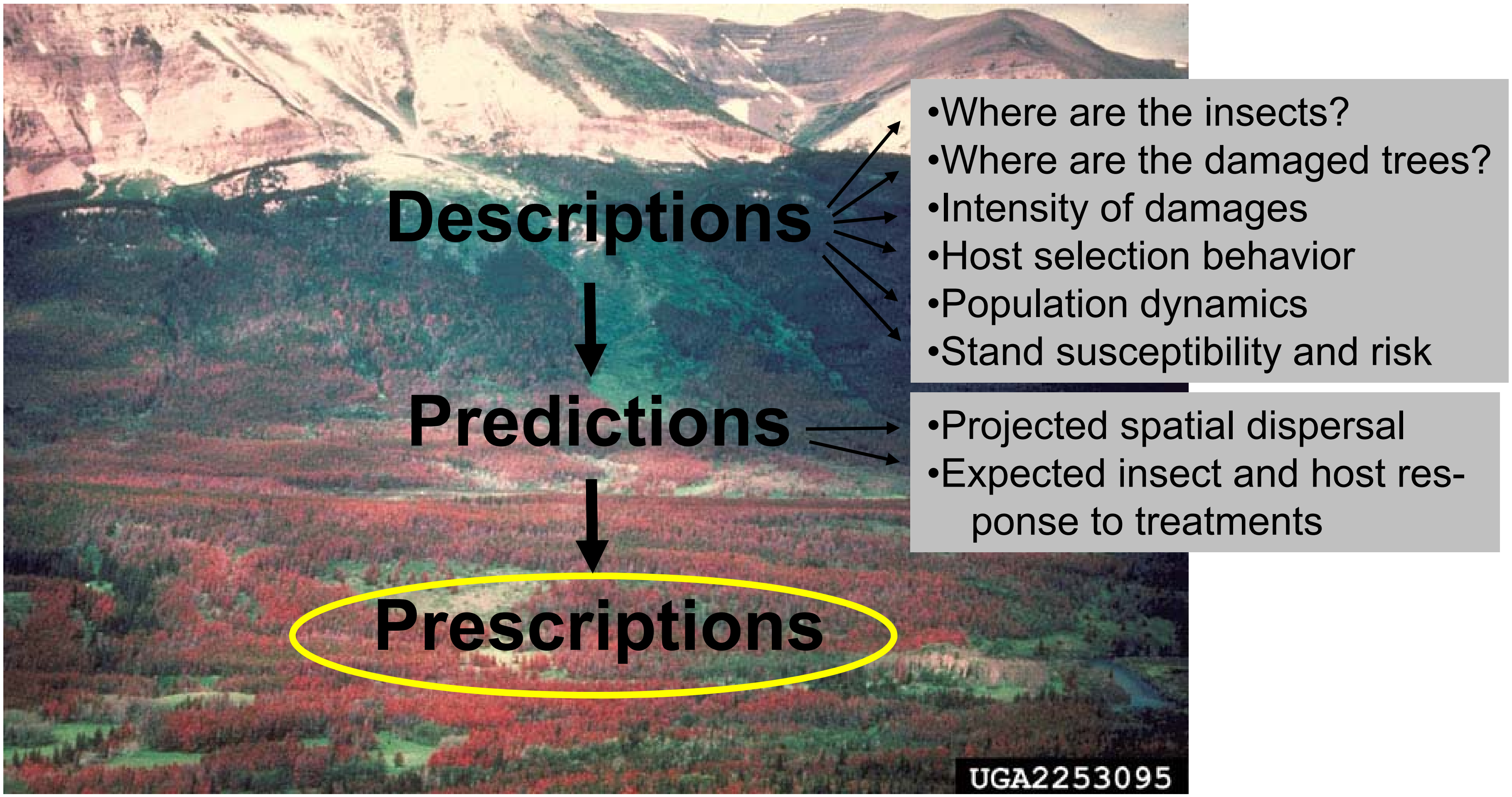
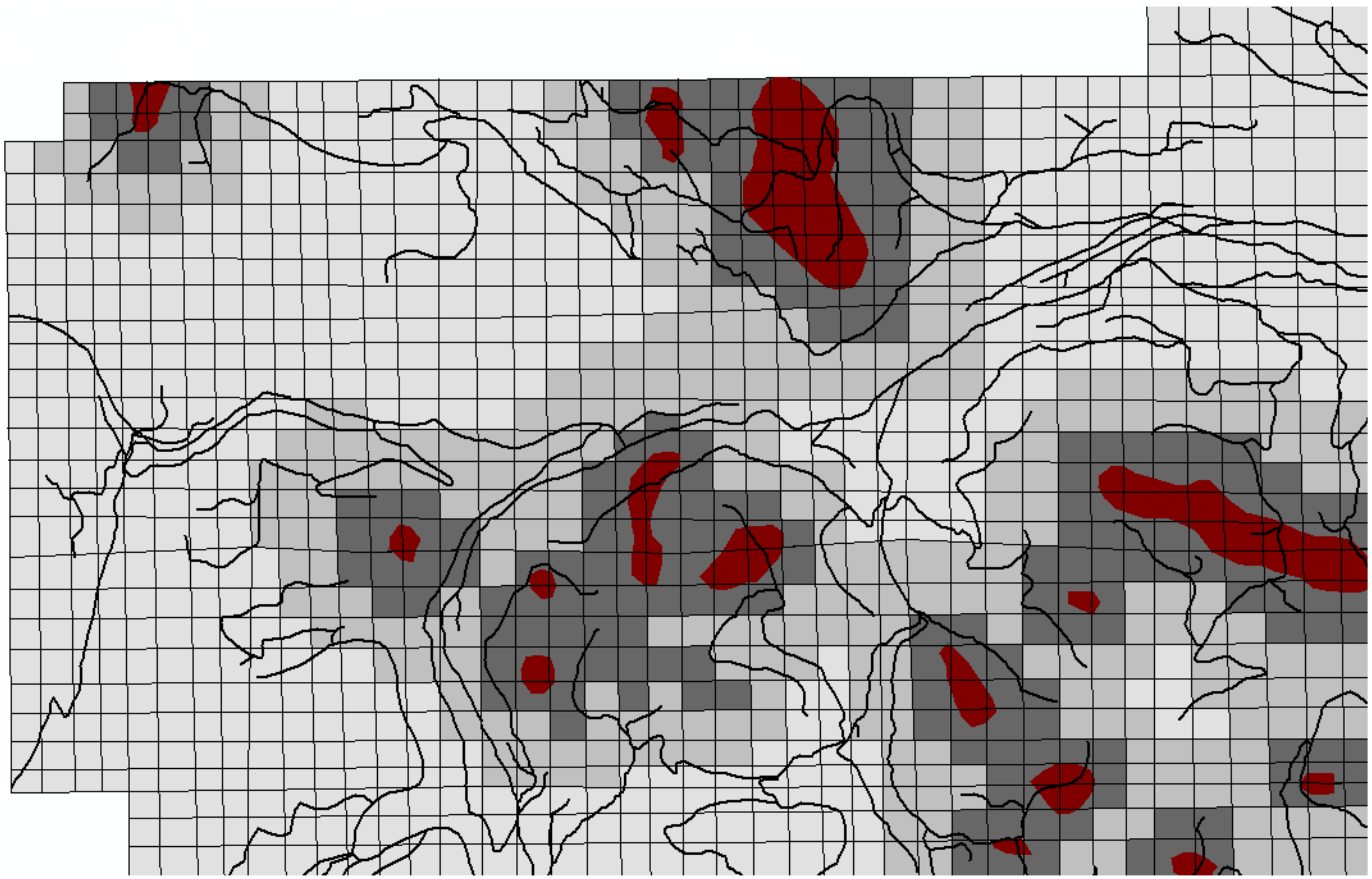


Image source: Mark McGregor, USDA Forest Service, Bugwood.org

The role of decision models



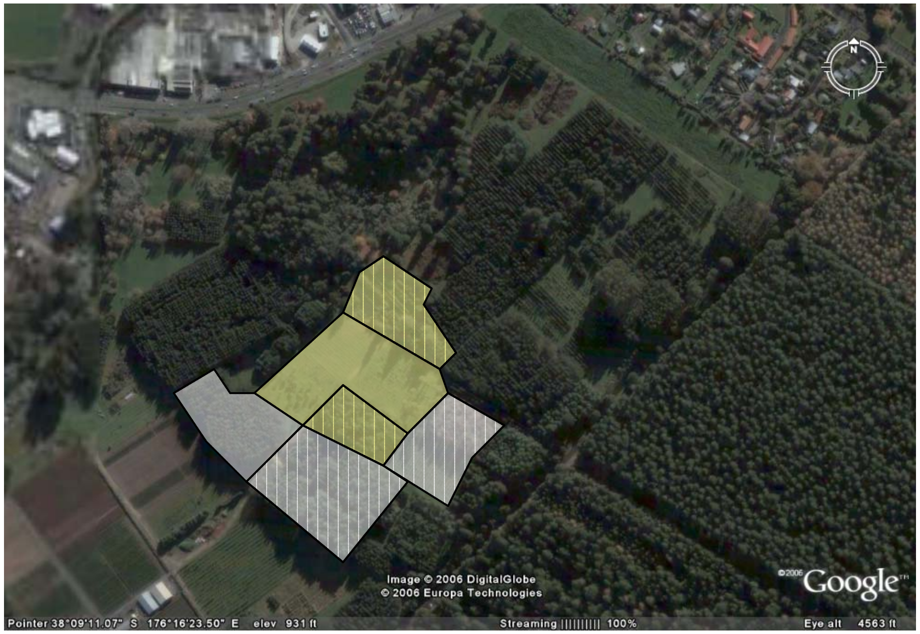
Models and Model Building Fundamentals

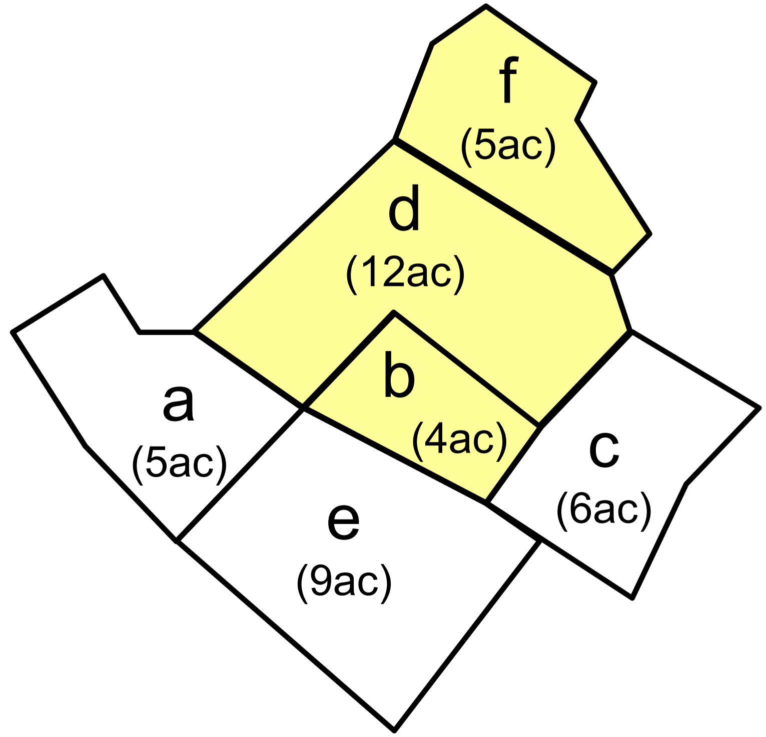
Models

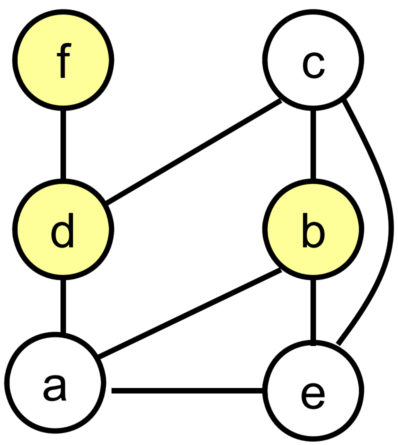
- Abstract representations of the real world
- Lack insignificant details
- Can help better understand the key relations in the system/problem
- Useful for forecasting and decision making

Model types

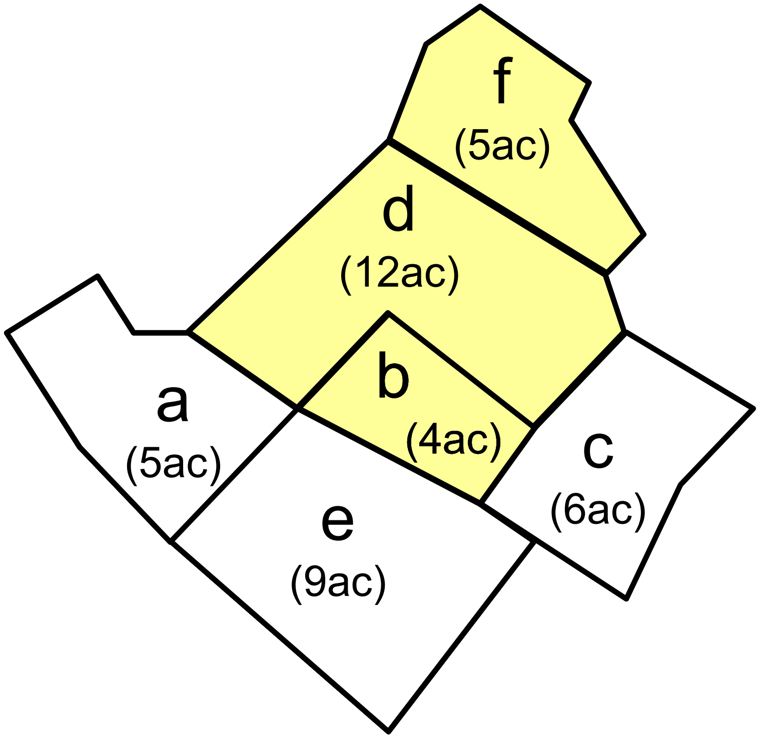
- Scale models (e.g., model airplane)
- Pictorial models (photographs, maps)
- Flow charts: illustrate the interrelationships among components
- Mathematical models







	A	B	C	D	E	F
A	1	0	0	1	1	0
B		1	1	1	1	0
C			1	1	1	0
D				1	0	1
E					1	0
F						1



Objective: Maximize financial return from cutting the stands

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.

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

2. *Objetive*:

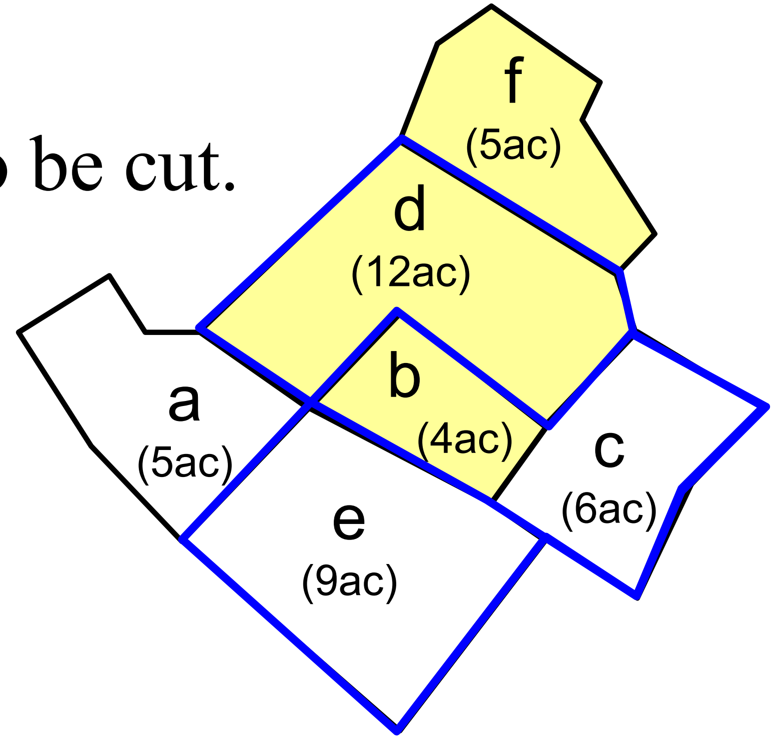
Let c_i denote the financial return from cutting stand i.

$$Max\ Z = c_a x_a + c_b x_b + c_c x_c + c_d x_d + c_e x_e + c_f x_f =$$

$$= \sum_{i \in N} c_i x_i, \text{ where N=\{a,b,c,d,e,f\}}$$

3. *Constraints* :

Adjacent stands are not allowed to be cut.



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

subject to:

$$x_a + x_e \leq 1$$

$$x_a + x_d \leq 1$$

$$x_b + x_c \leq 1$$

$$x_b + x_d \leq 1$$

$$x_b + x_e \leq 1$$

$$x_c + x_d \leq 1$$

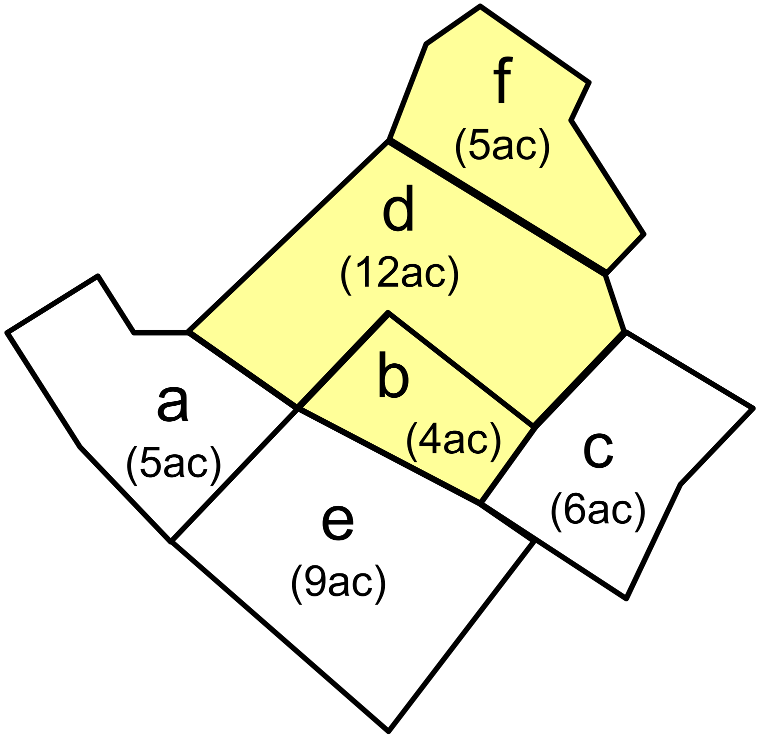
$$x_c + x_e \leq 1$$

$$x_d + x_f \leq 1$$

$$x_b + x_c + x_d \leq 1$$

$$x_b + x_c + x_e \leq 1$$

	A	B	C	D	E	F
A	1	0	0	1	1	0
B		1	1	1	1	0
C			1	1	1	0
D				1	0	1
E					1	0
F						1



A mathematical program:

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

Objective function(s)

subject to:

$$x_a + x_e \le 1$$
$$x_a + x_d \le 1$$
$$x_b + x_c + x_d \le 1$$
$$x_b + x_c + x_e \le 1$$
$$x_d + x_f \le 1$$
$$x_i \in \{0,1\}$$

Constraints

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)