Module G — Trade-offs: Overview of Optimization & Analytical Tools

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Outline

- Role of optimization
  - Overview
  - Classes of solution methods
- Single-objective tools
  - Deterministic setting (brute force, numerical search, LP)
  - Stochastic setting (decision trees, etc.)
- Multiple-objective tools
- Linked decisions

Role of Analytical Methods

- Identify "best" (optimal) solution—tie together alternative actions, objective function, and system model
  - How do you integrate all the components?
- Easiest with a single objective, but tools available for multiple objectives
- Easiest without uncertainty, but can incorporate natural (process) and knowledge (epistemic) uncertainty
- Solution method depends on the structure of the problem

Classes of Solution Methods

	No Uncertainty	With Uncertainty
Single Objective	Management Science; optimization tools	Classic Decision Analysis; decision trees
Multiple Objectives	Multi-attribute tradeoff tools & complex optimization	Multiple objective tools with variable inputs

Single Decision

	No Uncertainty	With Uncertainty
Single Objective	Graphical solutions Numerical solutions Derivation (Non-) Linear programming Integer programming	Decision trees Simulation Bayesian net
Multiple Objectives	Even swaps SMART AHP Goal programming	Decision trees (with MAU) SMART (with probabilities) AHP (with likelihoods)

Repeated (linked) Decisions

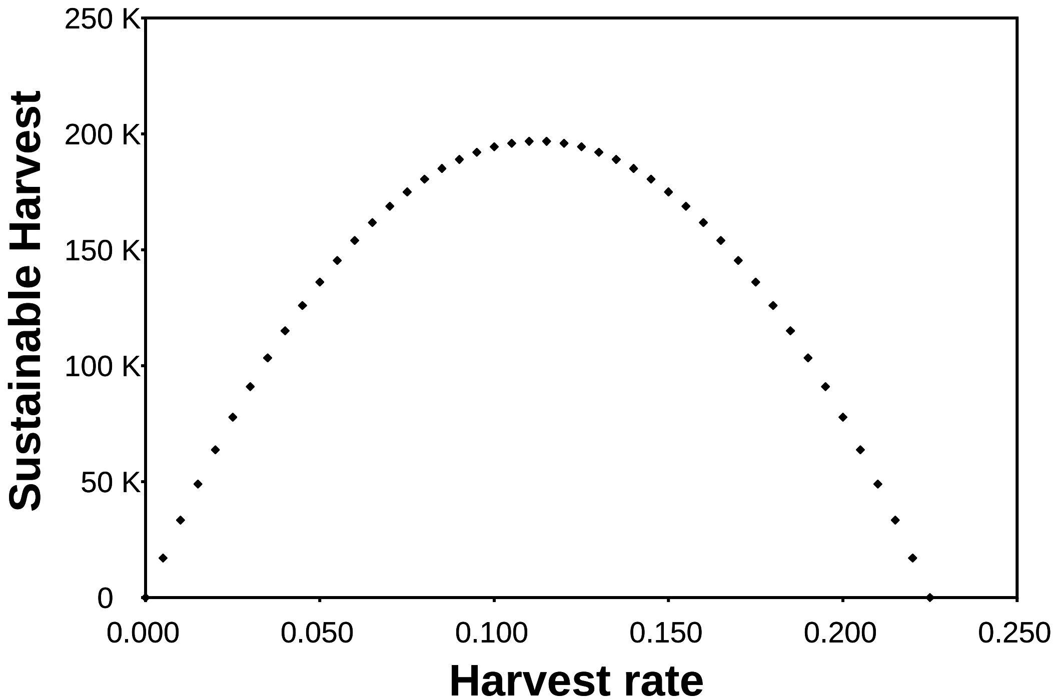
	No Uncertainty	With Uncertainty
Single Objective	Dynamic programming	Stochastic dynamic programming Adaptive stochastic dynamic programming
Multiple Objectives	?	?

Single-objective Tools

1. Deterministic setting

- Alternatives: single continuous decision variable
  - e.g., harvest rate, amount of herbicide, size of biocontrol release, etc.
- Predict outcomes (objective) as a function of the decision variable(s)
  - Typically there are implicit trade-offs, so you expect some middle value to be optimal
- Solution methods:
  - Brute force
  - Closed-formed solutions (calculus/differentiation)
  - Numerical solutions (mathematical search methods)
  - Constrained optimization (mathematical solution)

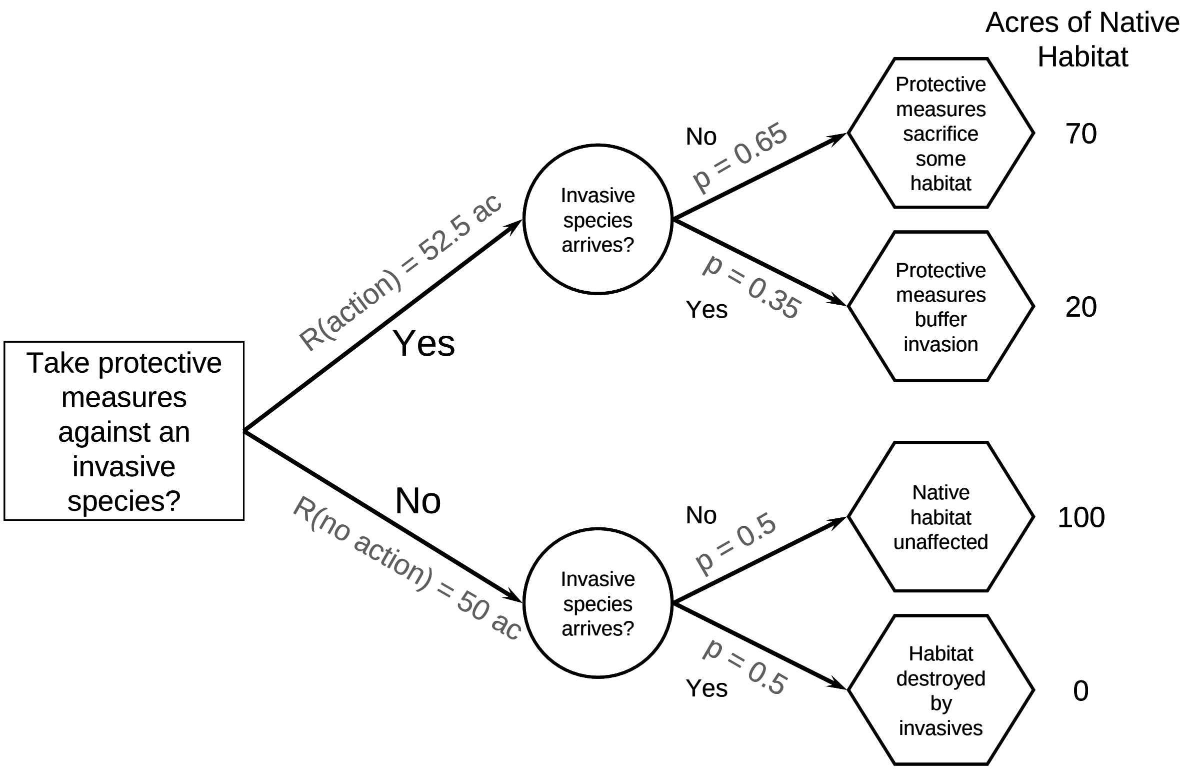
Graphical Optimization



2. Stochastic setting

- Need to predict each outcome and its *probability*
- Common tool: decision trees
  - "Sum up" to find the expected value of each action
- Then, relatively easy to spot the "best" (optimal) solution

Decision Tree



In pairs

- Come up with one example of a single-objective problem in your work setting

Multiple-objective Tools

Multiple-objective Strategies

- First, simplify the problem as much as possible
- Then, do one of the following:
  - Reduce to a single-objective problem
  - Treat as a trade-off problem
  - Negotiate a solution (from a set of best compromises)

Simplify the Problem

Expected Return	Actions			Eliminate
Objectives	Status quo	Minor repair	Major repair	Re-build
Cost ($M)	0 + 2 = 2	2	12 + 1 = 13	20
Environmental Benefit (0-10)	1	3	10	10
Disturbance (0-10)	0	1	7	10
Silt runoff (k ft^3) (1 k ft^3=$500K)	5 – 4 = 1	1	3 – 2 = 1	3
Water Retention (MG)	41	41	41	39

Eliminate Combine

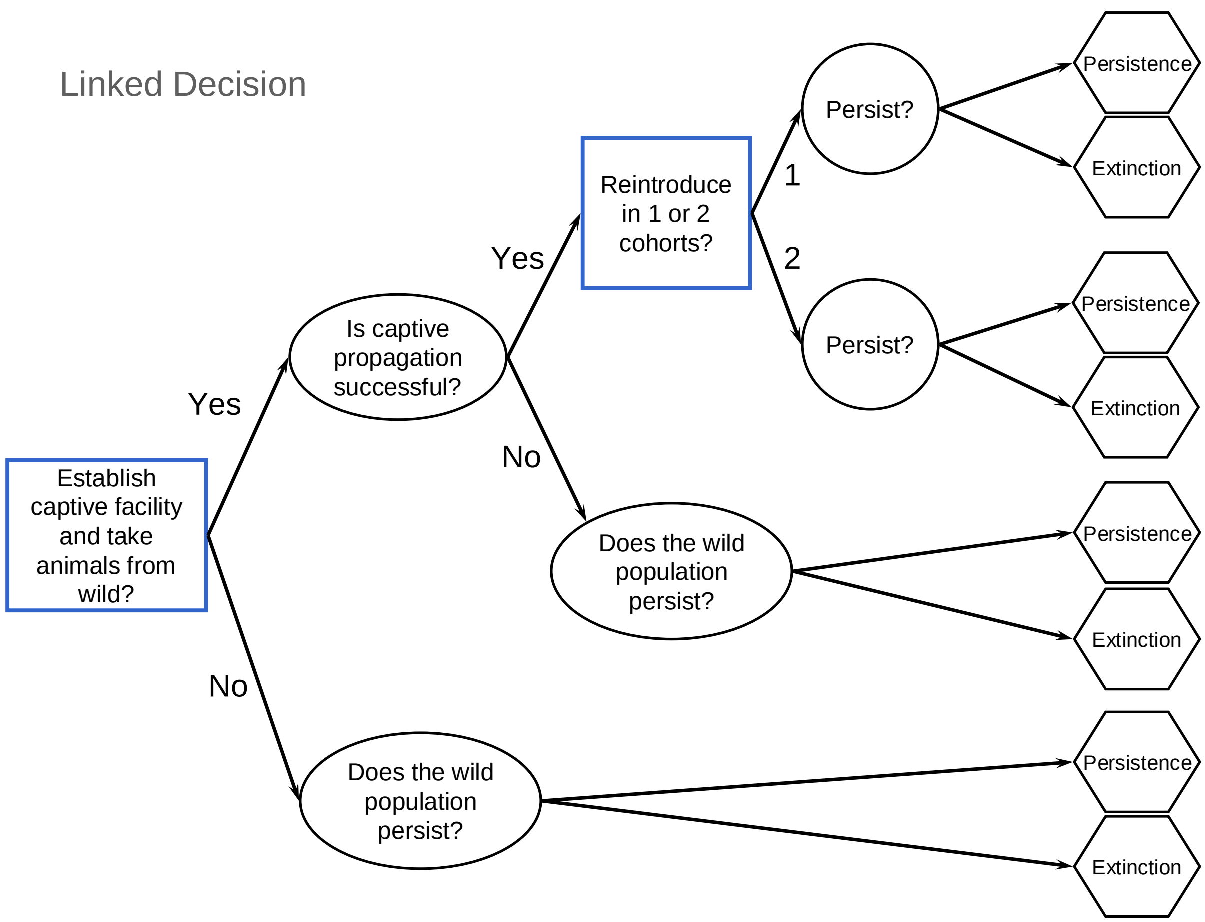
Manage Tradeoffs

Objectives	Alternatives		
	Status quo	Minor repair	Major repair
Cost ($M)	2	2	13
Environmental Benefit (0-10)	1	3	10
Disturbance (0-10)	0	1	7

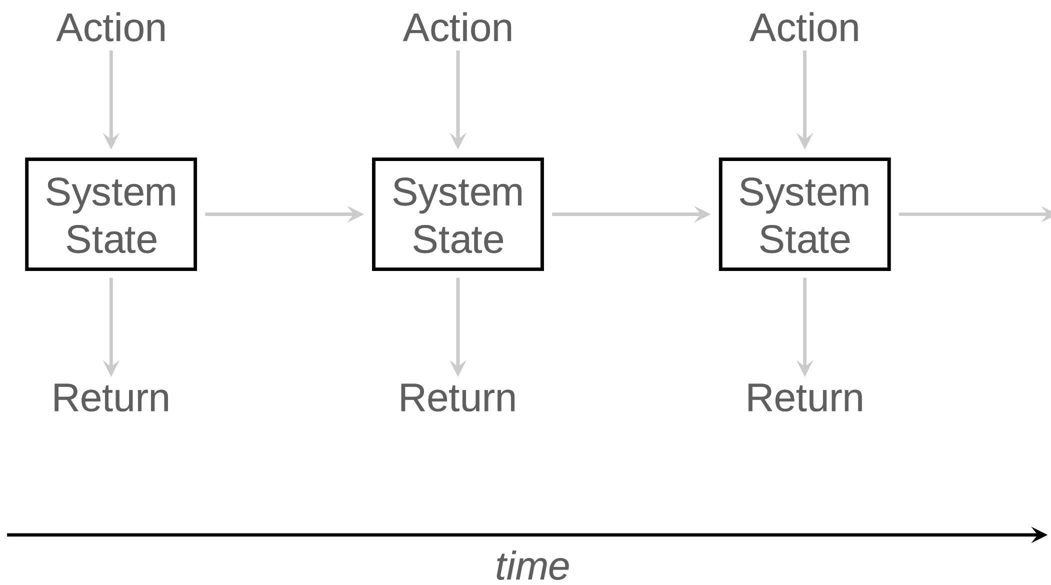
In pairs

- Come up with one example of a multiple-objective problem in your work setting

Linked Decisions



Dynamic Decisions



Dynamic Programming

- Dynamic programming is a method for solving problems where temporal dynamics are important
- Recognizes that each action accrues a current return but also changes the state of the system, which can affect future returns

SDP and ASDP

- Stochastic dynamic programming incorporates uncertainty due to stochastic events
  - Optimal strategies anticipate risk
- Adaptive stochastic dynamic programming goes one step farther and incorporates uncertainty due to lack of knowledge
  - Optimal strategies anticipate benefits of learning

Other Methods

- Finding approximate solutions
  - Some big problems are too big to be solved by the previous methods in any reasonable amount of time.
  - Mathematical search methods, like genetic algorithms, can be used to find an approximate solution.

Summary

- The goal is to *solve* the problem…that is,
- To identify the best alternative action, as measured by the objectives, using predictions from the models
- A wide variety of analytical tools exists to find solutions
- The key is knowing where to look in the toolbox

Quiz

- What type of decision problem are the following examples? What tool might be useful for solving them?
  - Whether to relocate or start captive breeding of Devil's Hole Pupfish

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  - Management of early successional fields on refuges in the Northeast

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  - Stocking levels of bass in Adirondack lakes

  - Annual harvest regulations for woodcock

  - Whether to invest in a study of the costs & benefits of outsourcing

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Putting it all together

- Problem definition
- Objectives
- Alternatives
- Consequences
- Tradeoffs

Now what?

- You've used *optimization* to identify the action among a set of *alternatives* that best achieves your *objectives*, given your current understanding of the *consequences* of each alternative.
- Decision: Implement the preferred action.