Scenario Optimization Tool for CAST

STAR: Opportunities for Addressing Goal Team Needs

24 May 2018

Daniel Kaufman

Vision of "Cost-benefit optimization"

Design and progress

Near-term Future and looking ahead

Co-benefits and other ideas

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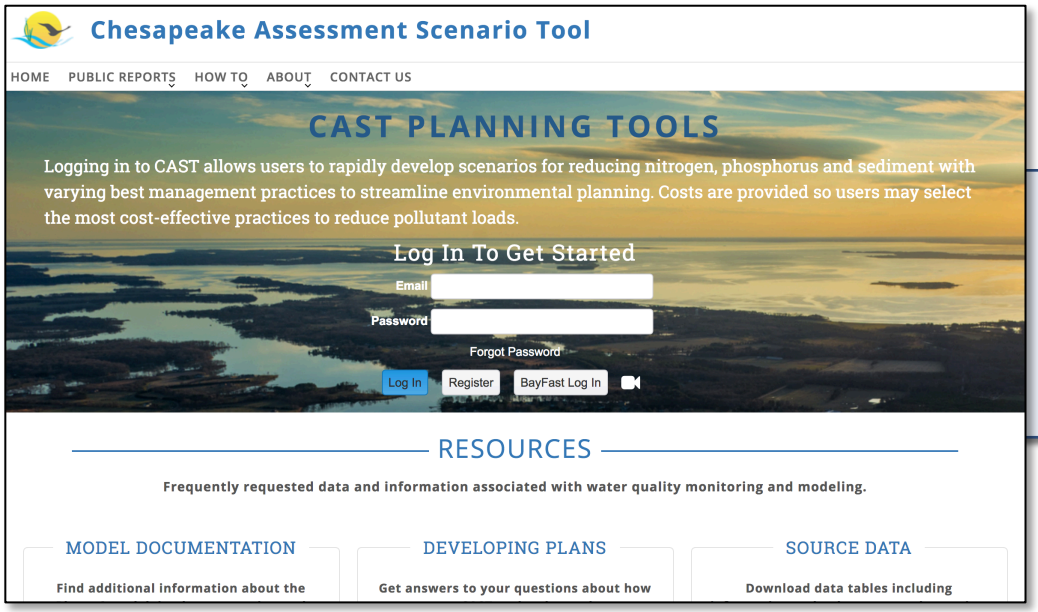
The Vision of "Cost-benefit Optimization"



Target Loads

Low cost

Chesapeake Assessment Scenario Tool (CAST) estimates nitrogen, phosphorous, and sediment load impacts and the financial costs of implementing best management practices (BMPs).

The Vision of "Cost-benefit Optimization"

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The Vision of “Cost-benefit Optimization”

There is a large number of decision variables, non-linear cascading effects of Best Management Practices (BMPs), and it takes time to become an expert user of the system.

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The Vision of "Cost-benefit Optimization"

Build a module into the system that provides guidance:

Analyze the space of potential BMP implementation scenarios and identify low-cost options

What is meant by optimization?

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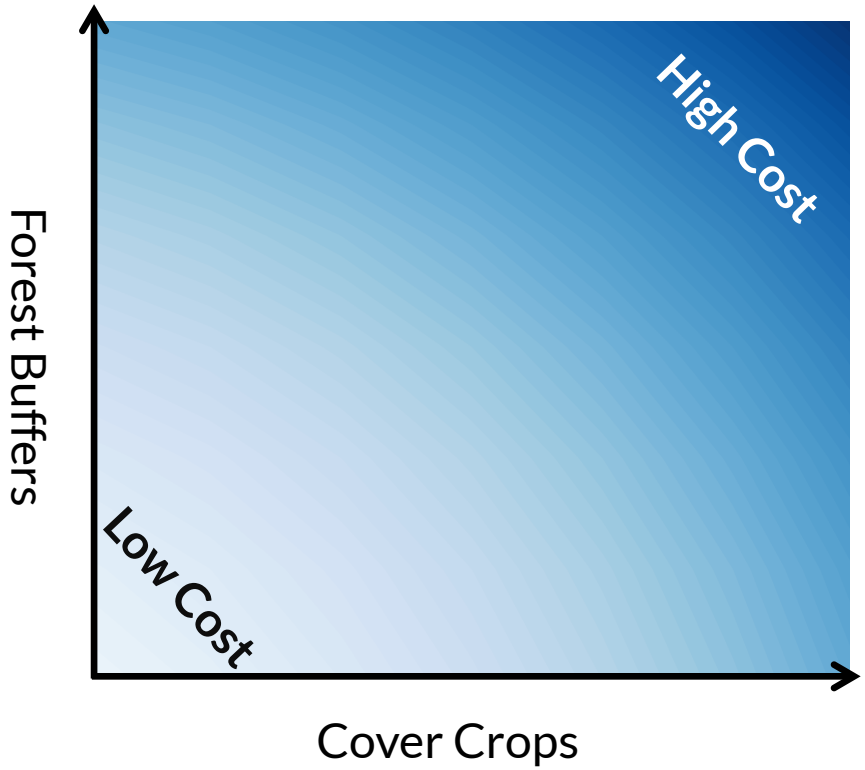

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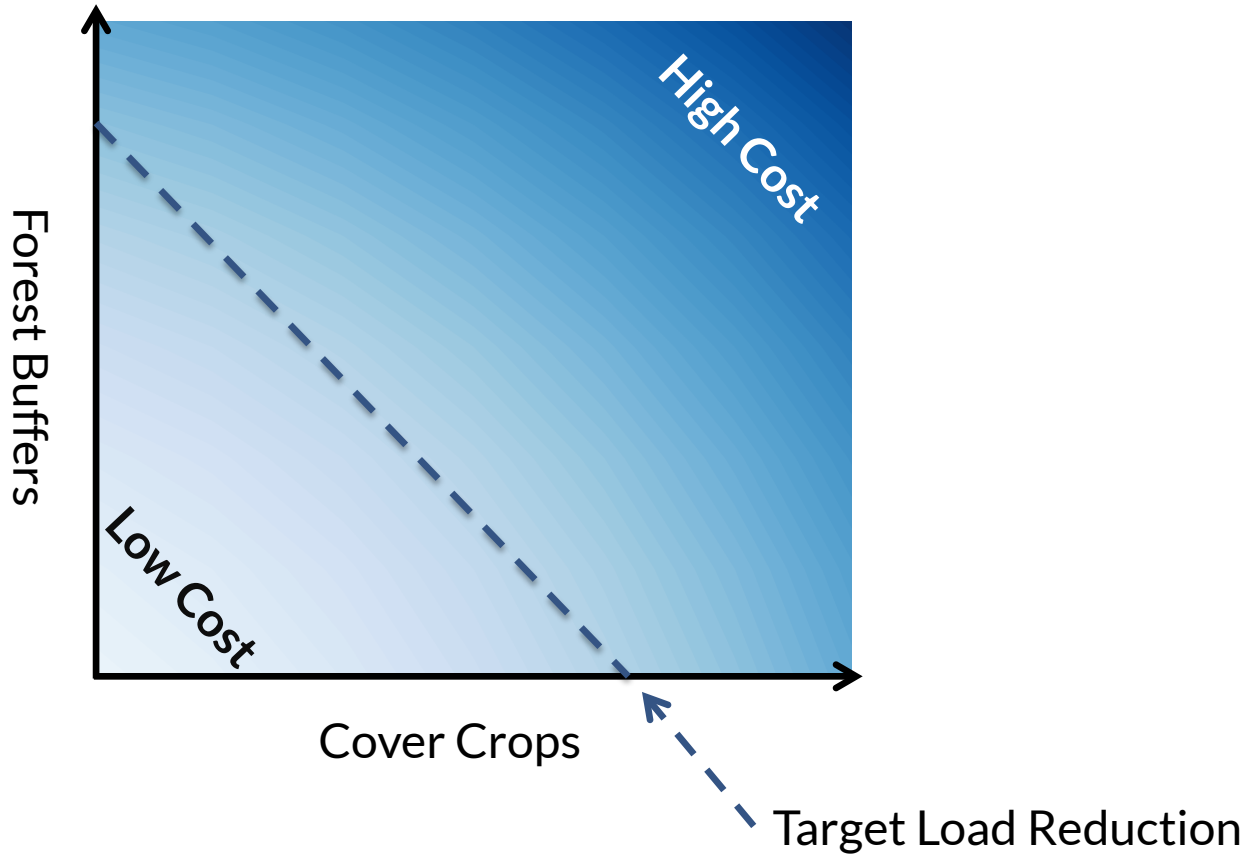

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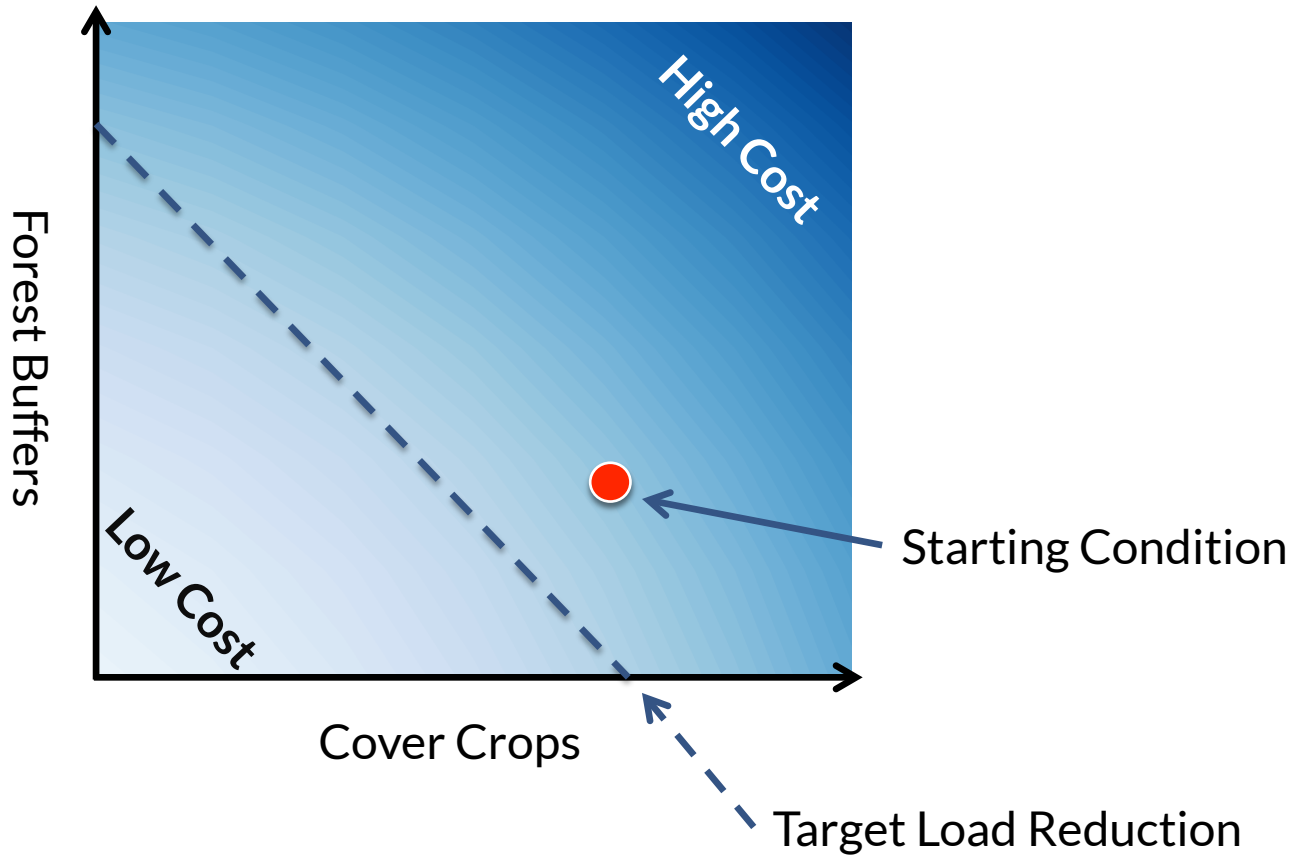

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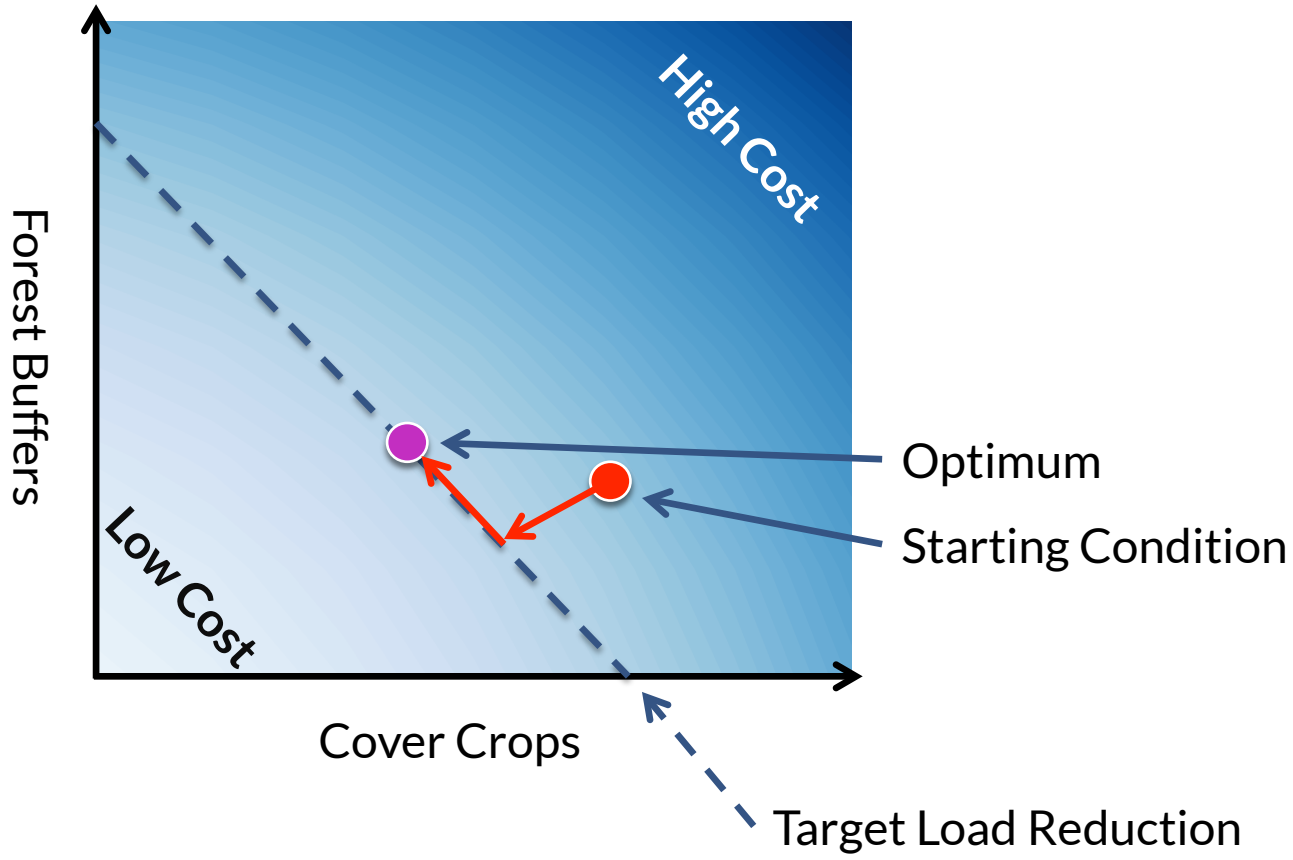

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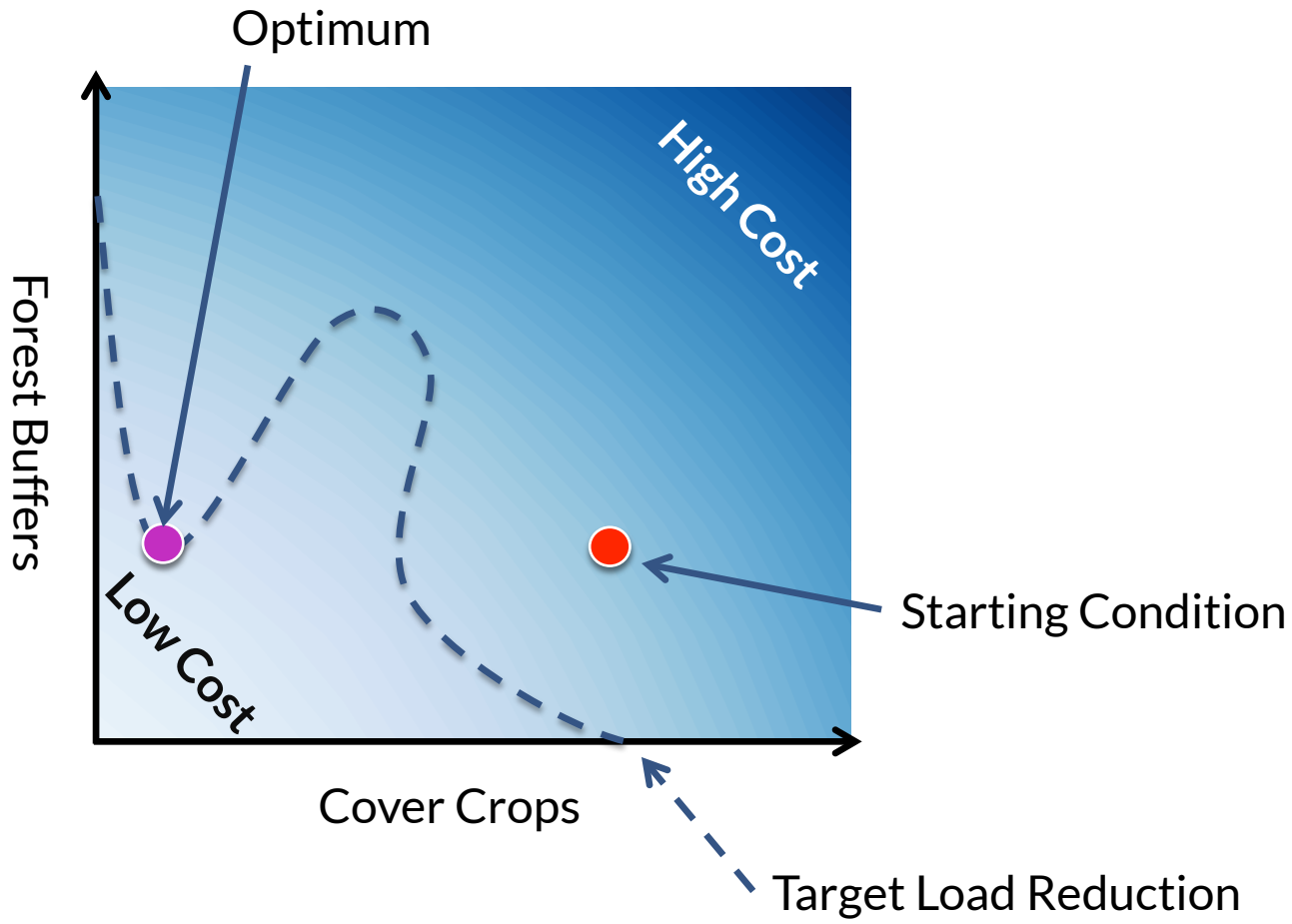

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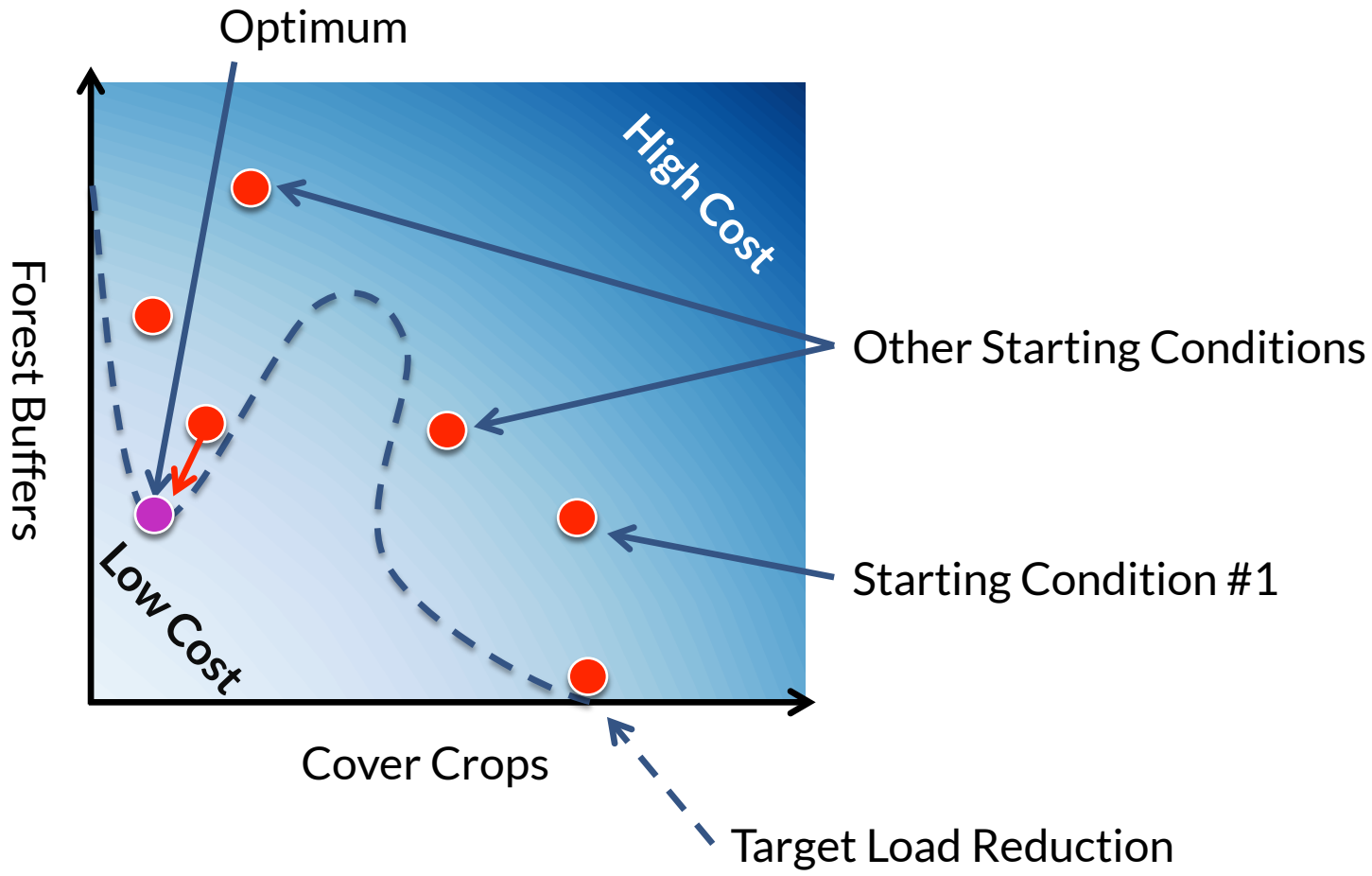

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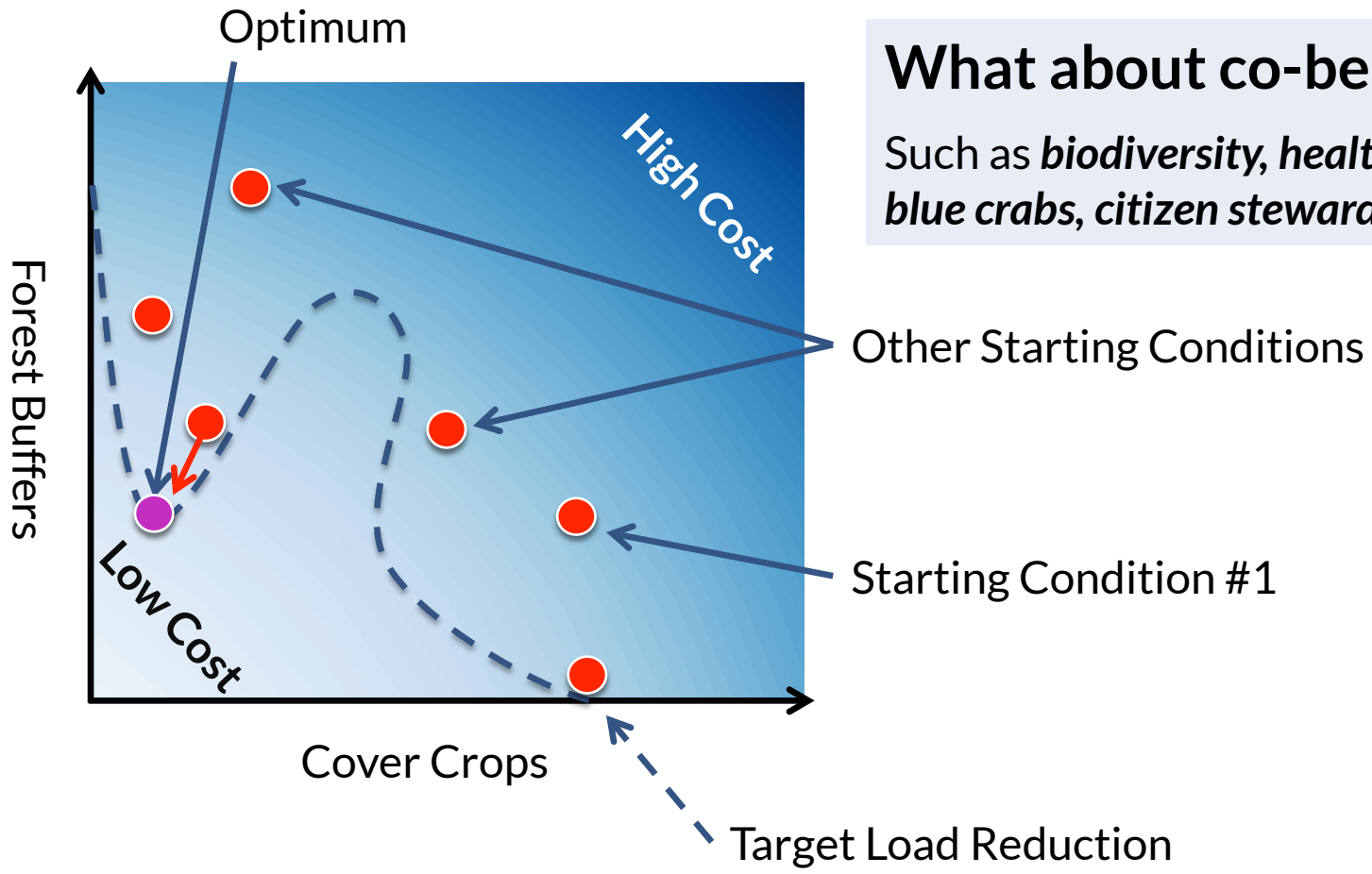
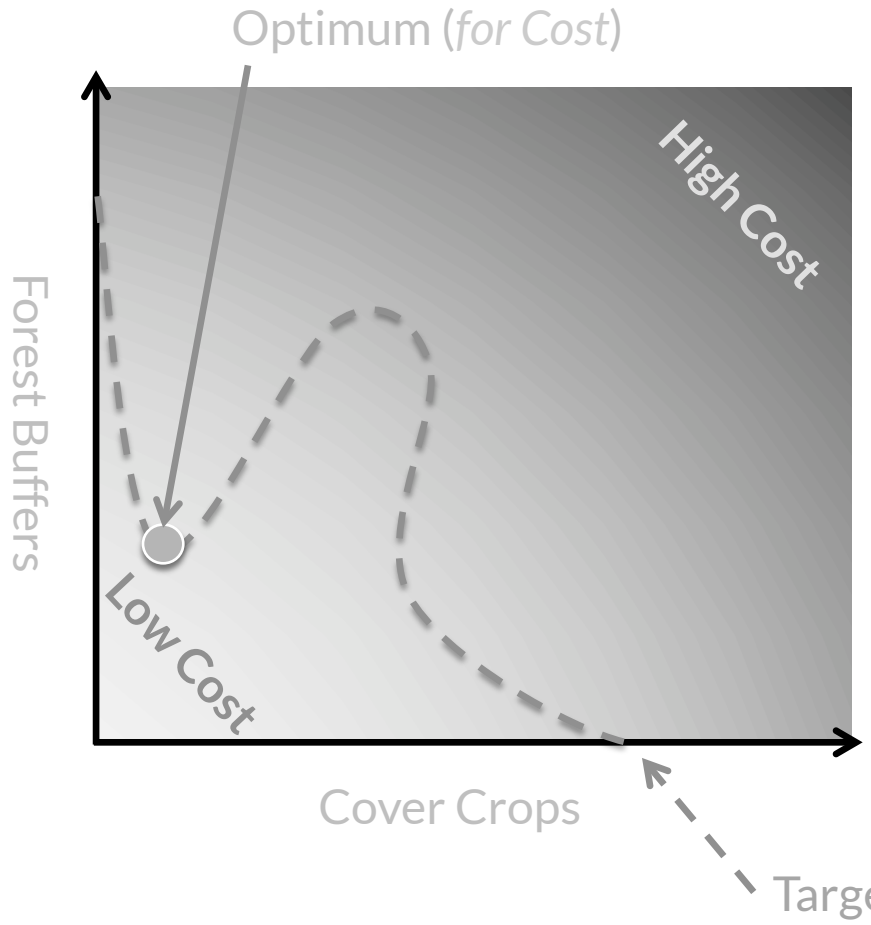
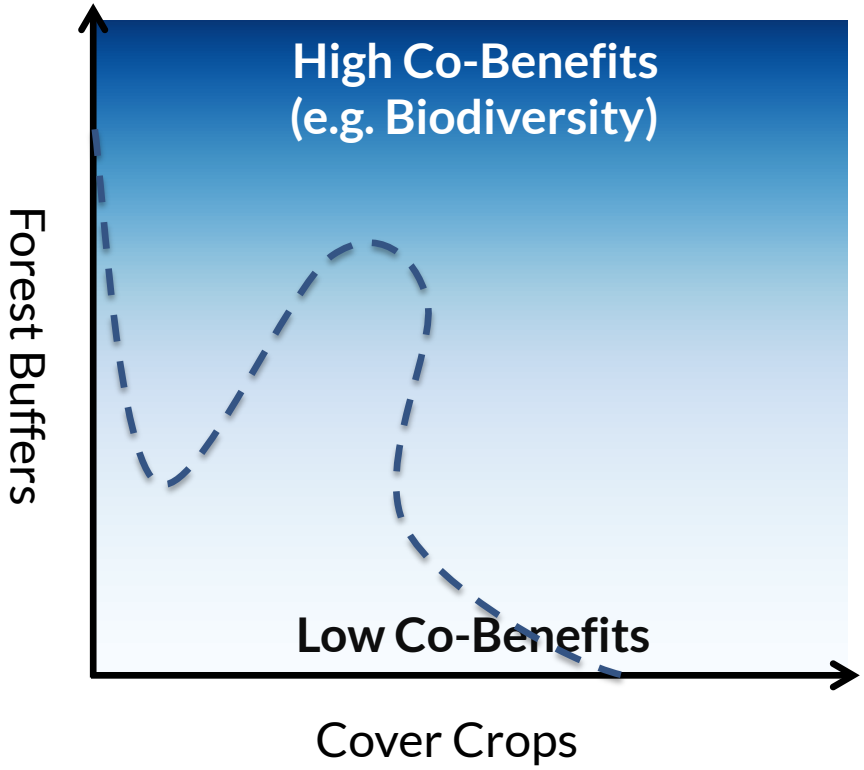


What about co-benefits?

Such as ***biodiversity, healthy watersheds, blue crabs, citizen stewardship***

Multi-Objective Optimization





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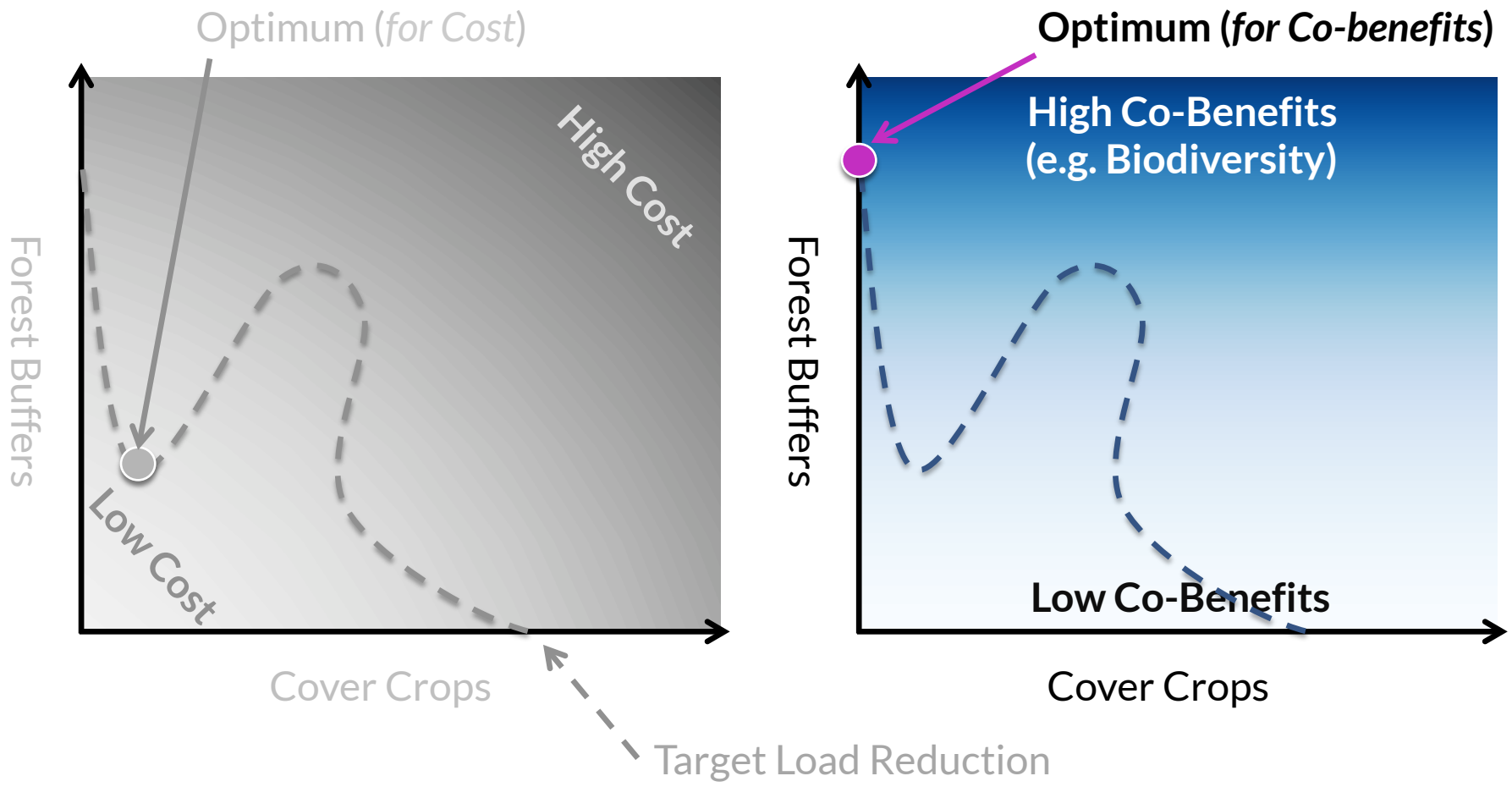

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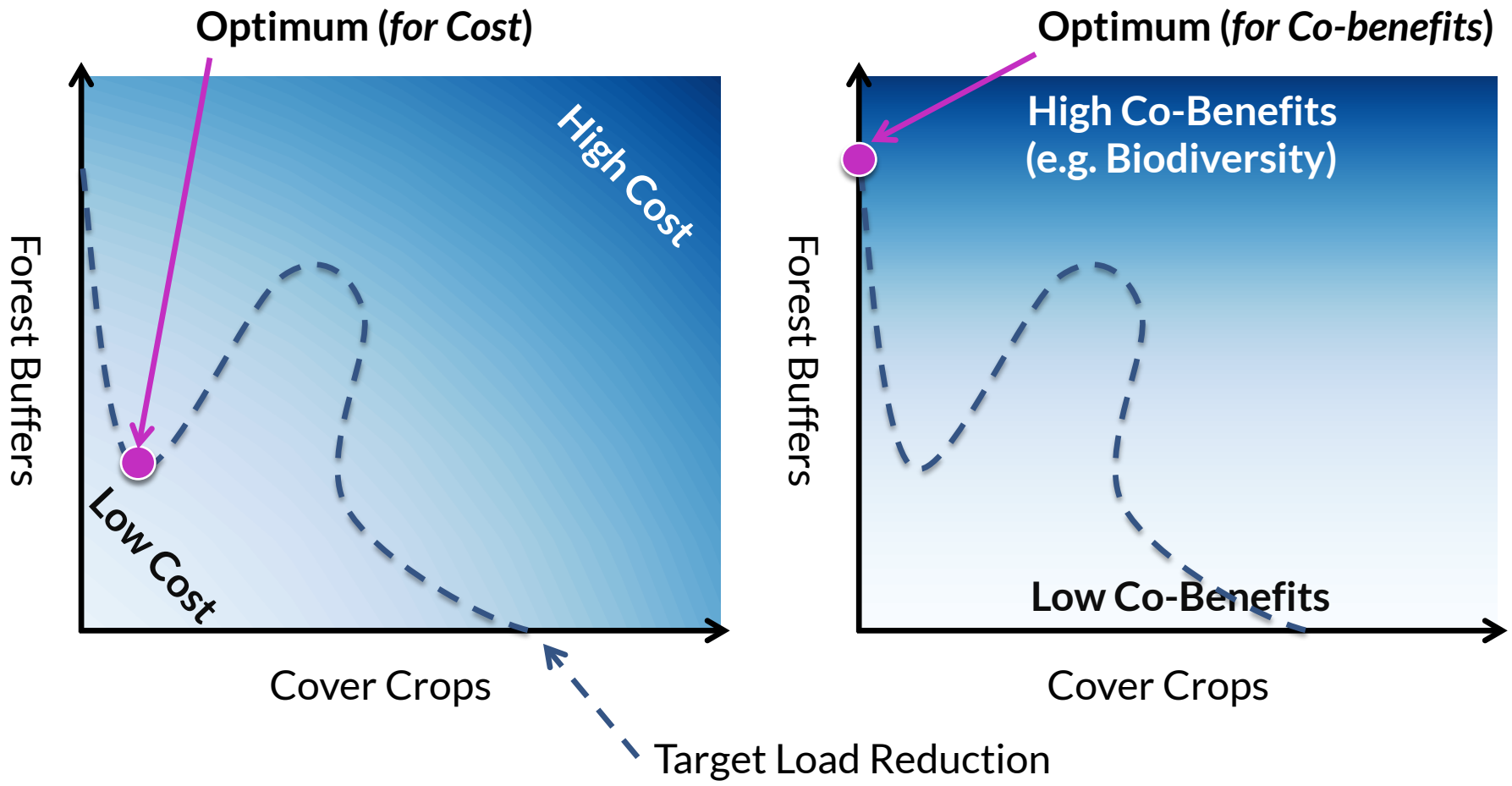
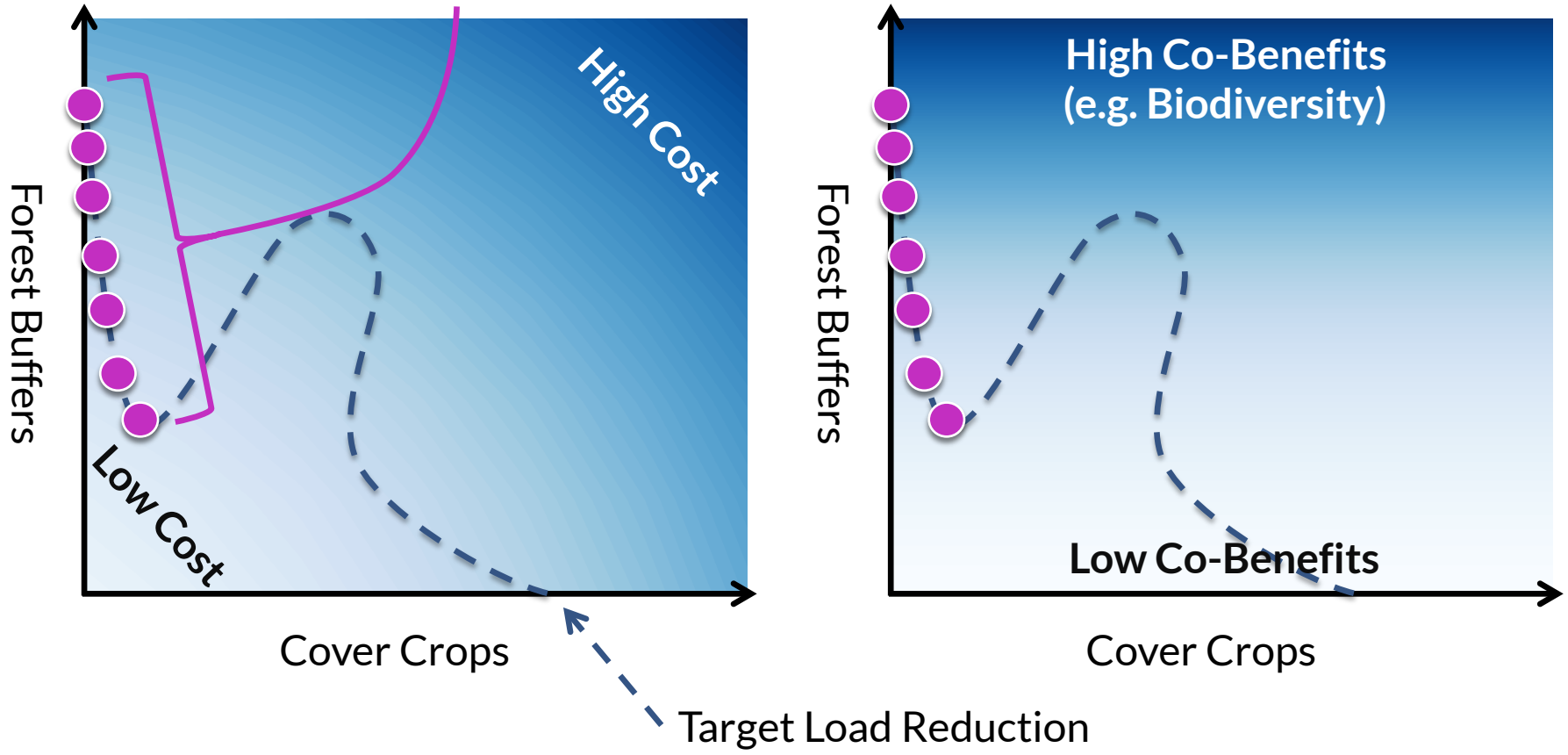


Multi-Objective Optimization

Multi-Objective Optima include tradeoffs

All of these are "best", with different tradeoffs



Vision of “Cost-benefit optimization”

Design and progress

Near-term Future and looking ahead

Co-benefits and other ideas

Optimization Model Description

Objective:

(Primary) Minimize the total annual costs of BMP implementation (includes capital, installation, opportunity, maintenance)

(Secondary) Maximize co-benefits

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- Tons of manure transported

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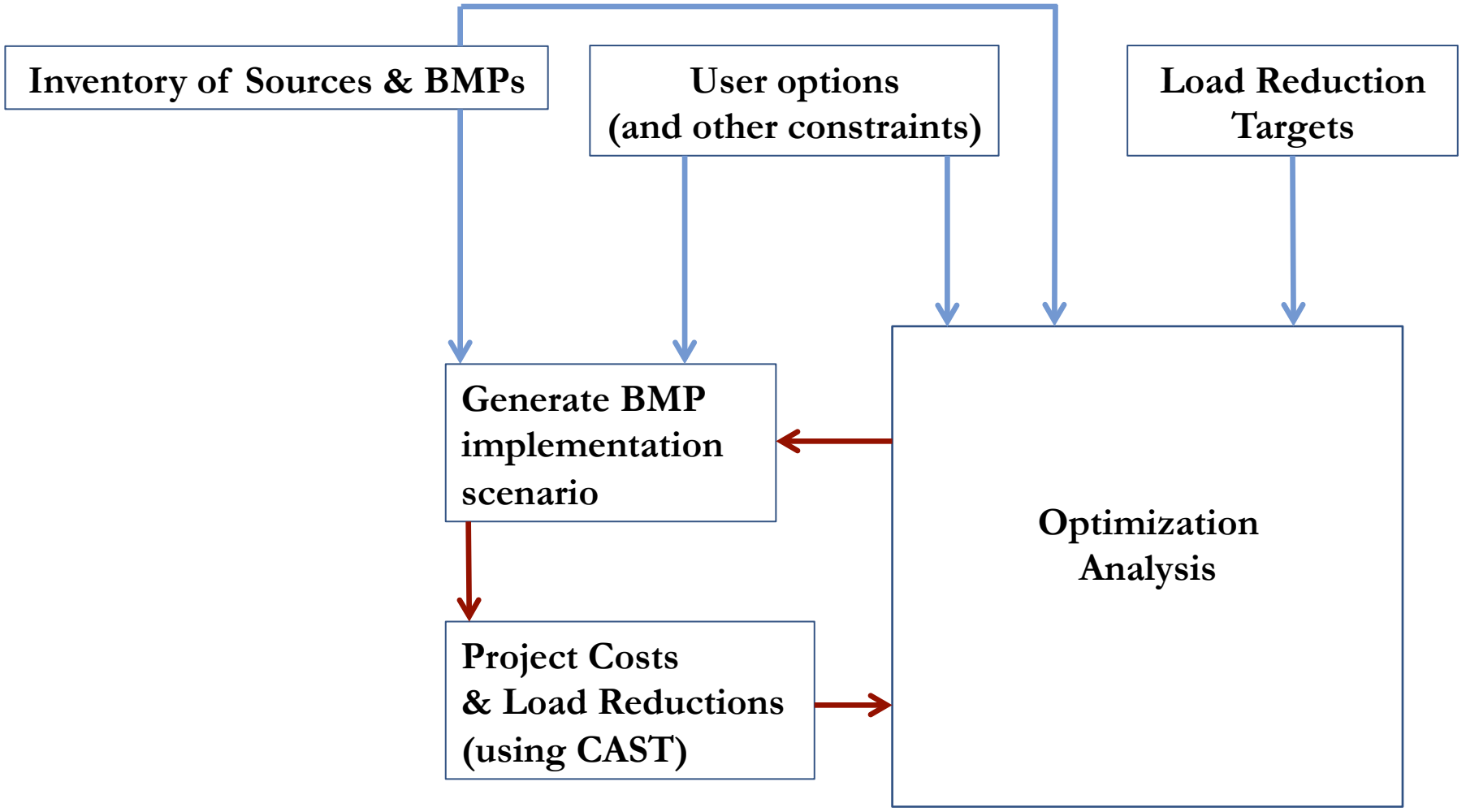
Basic Constraints:

- Scale/region of scenario (and/or agencies)
- Nitrogen and Phosphorous simulated load reductions ≥ reduction targets
- BMP'd acres ≤ available acres (by segment and land-use)
  - BMP'd roads ≤ available miles
  - BMP'd shorelines ≤ available miles
  - BMP'd animals ≤ available animal counts

Other Constraints:

- BMP constraints, for example:
  - agricultural land retirement ≤ *X* acres
  - cover crop oats ≥ *X* % of agricultural acres
- Land use restrictions for certain BMPs
- Capital limitations for certain sectors?

Optimization Tool Schematic



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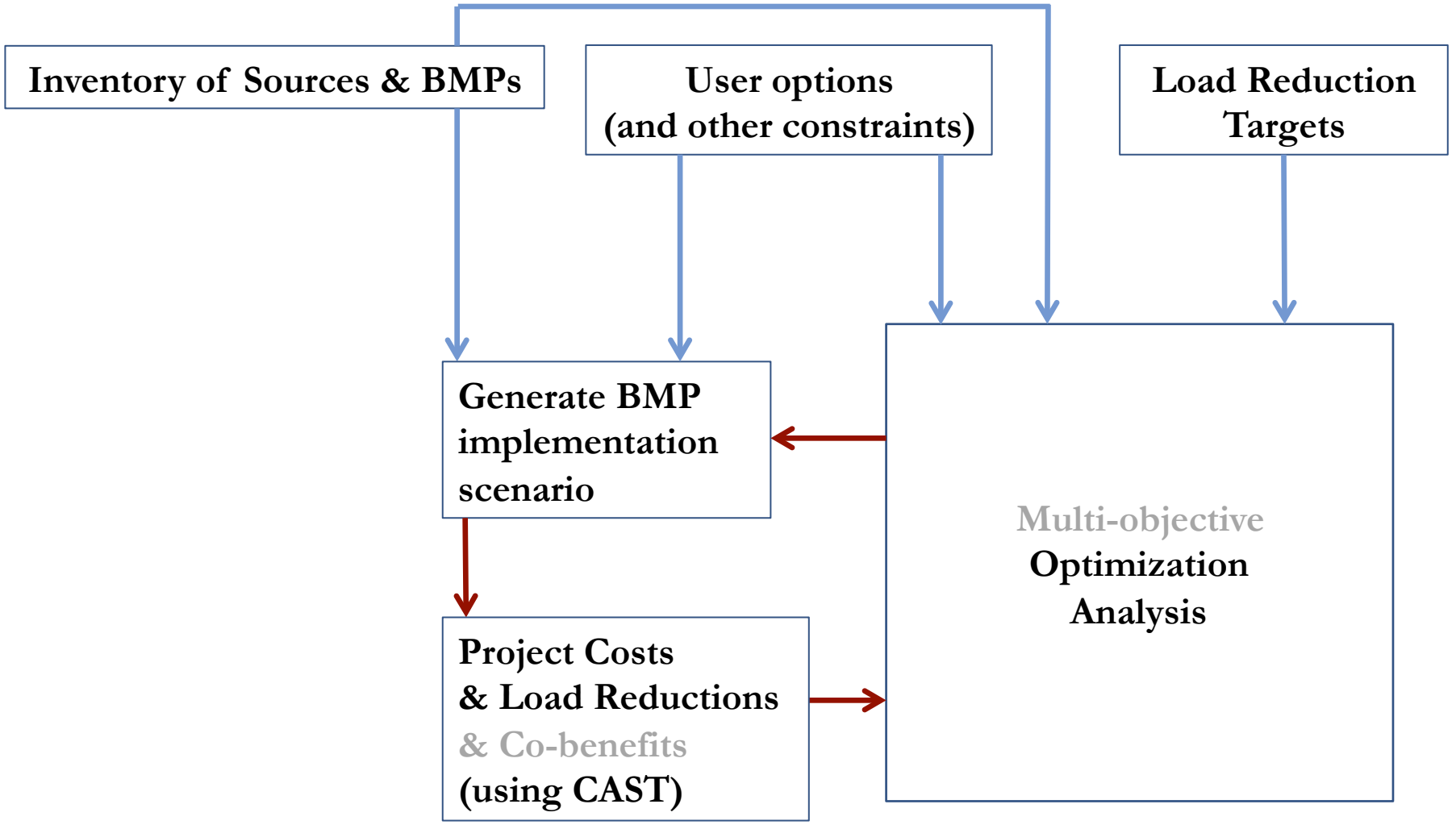
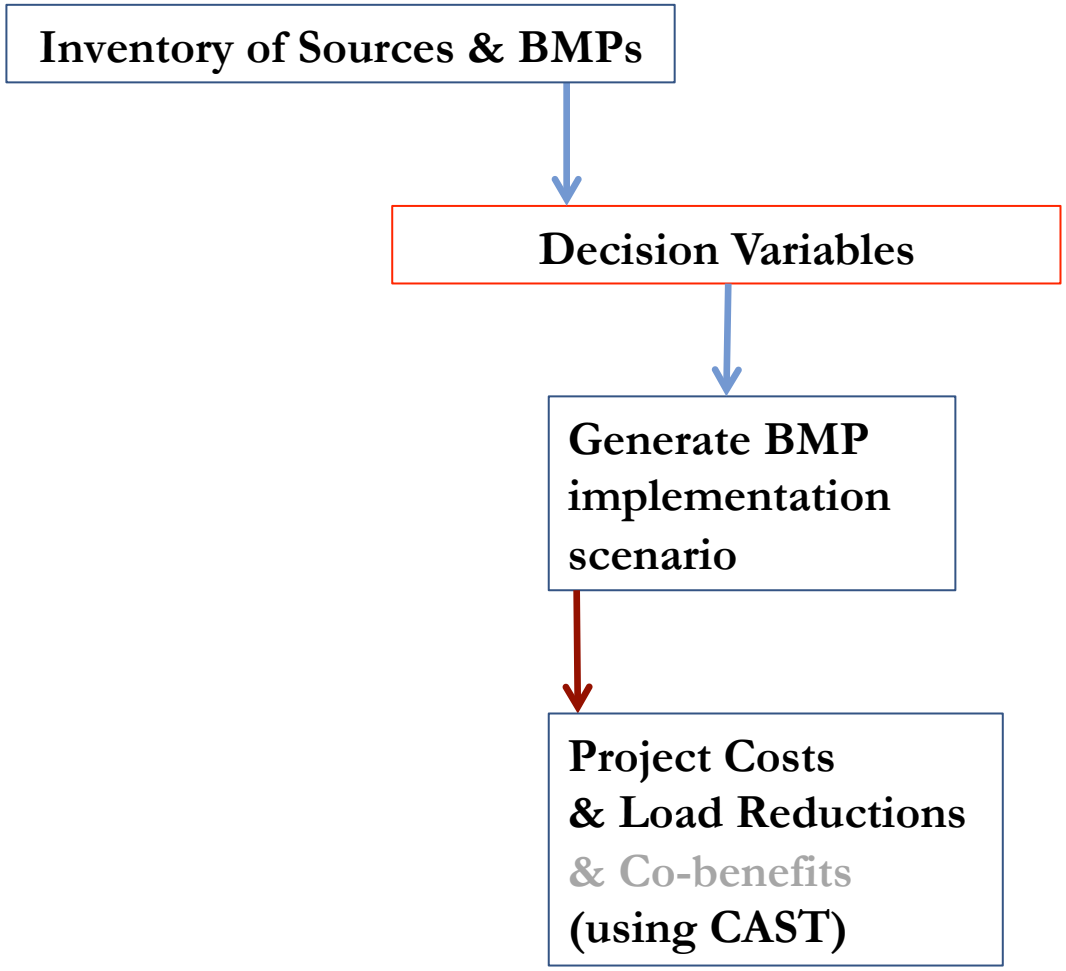


Development: Where do things stand?



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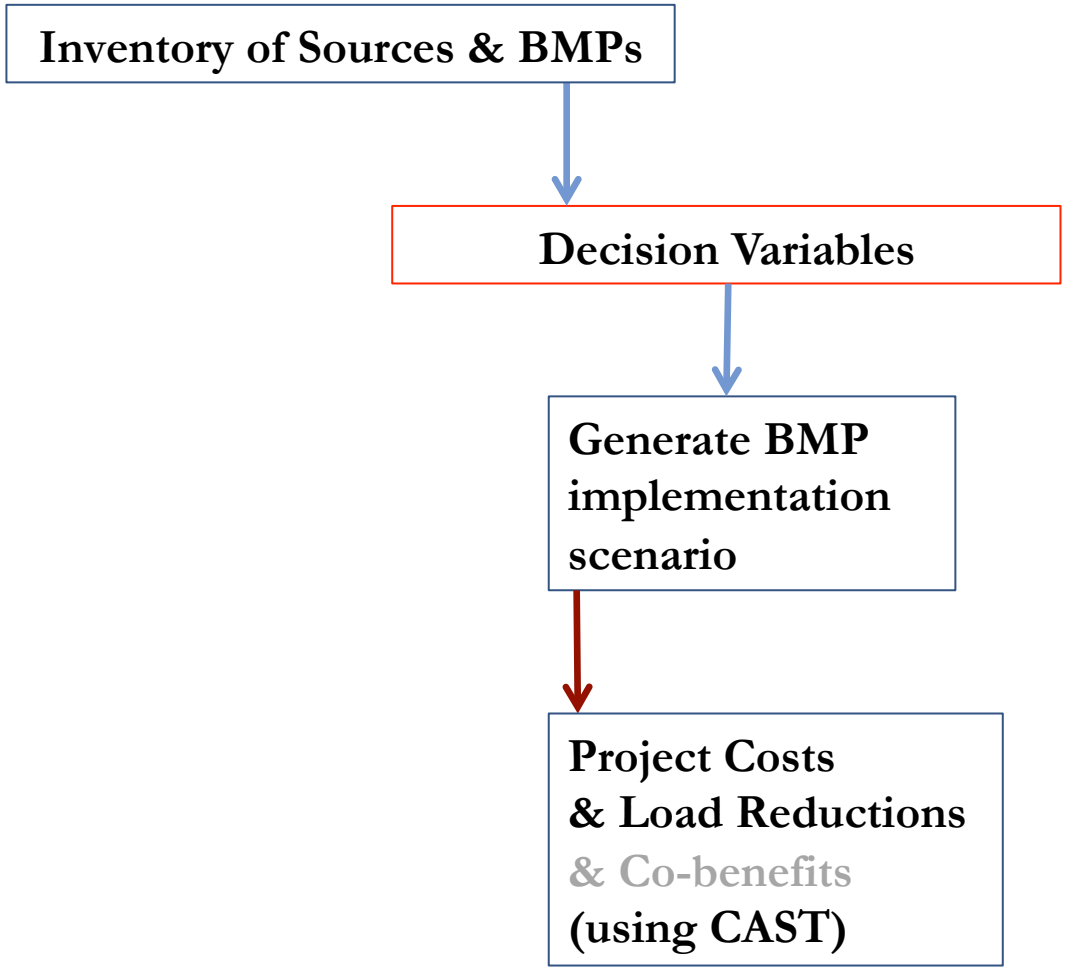


Scenario Generator

Python code - v0.3

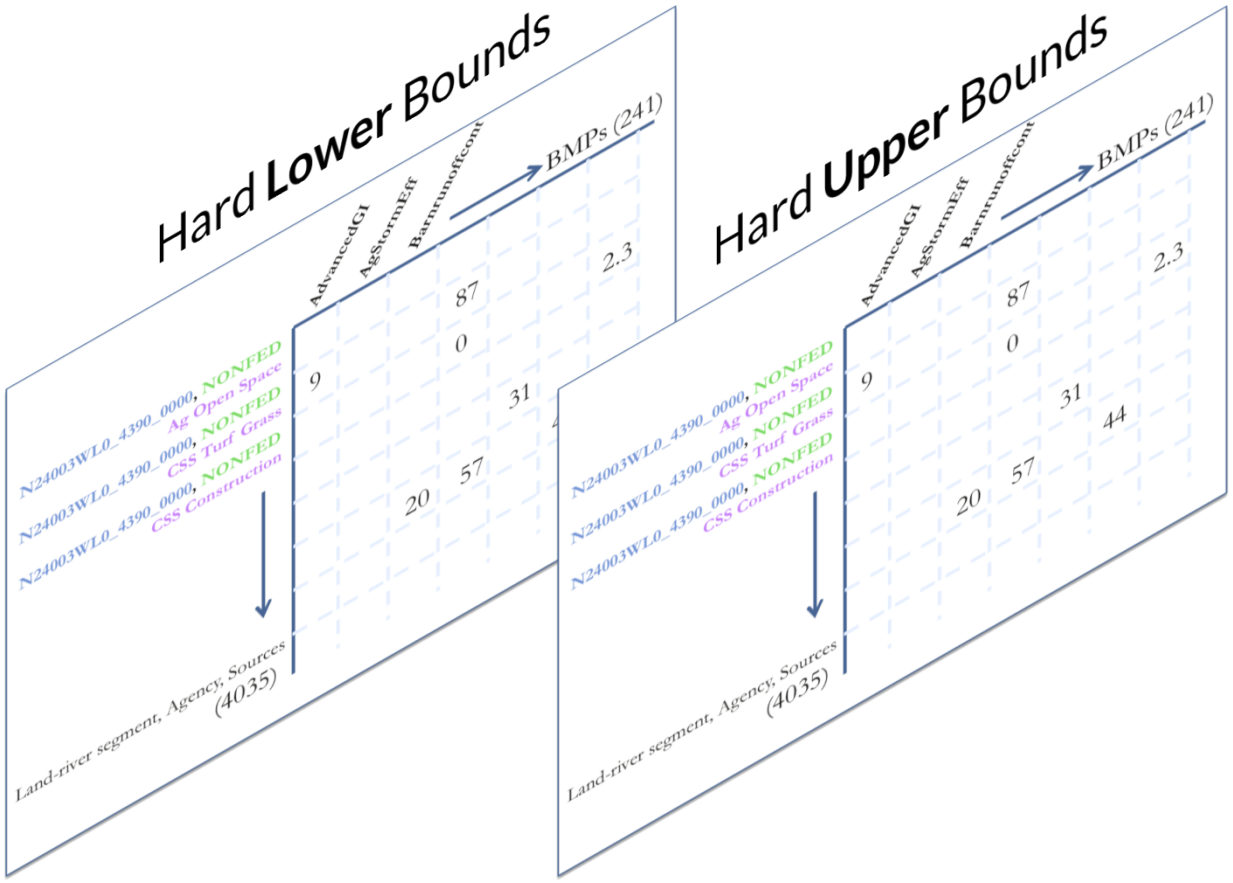
Preliminary graphical interface design

- metadata
- decision variable selection
- constraints

- Documented
- Cloned on CBP cloud server
- Percent bounds for most BMPs

A decision variable space is generated

For Land, Animal, and Manure



- **20% sparse when including all land river segments, agencies, sources, BMPs**
- **~200,000 knobs to turn for Anne Arundel County**
- **Basic constraints determine hard upper and lower bounds**

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Sampling Experiments (batch/greedy)

Goals of this effort:

- **Provide insight for appropriate algorithms**
- **Produce a scenario comparison tool**

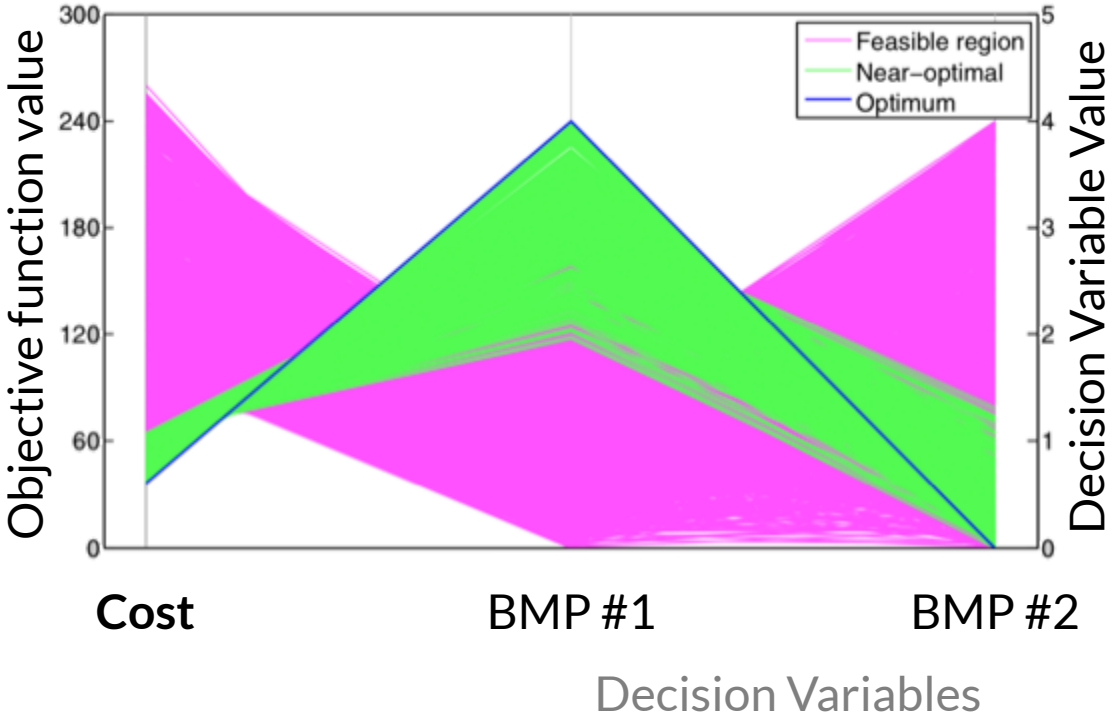


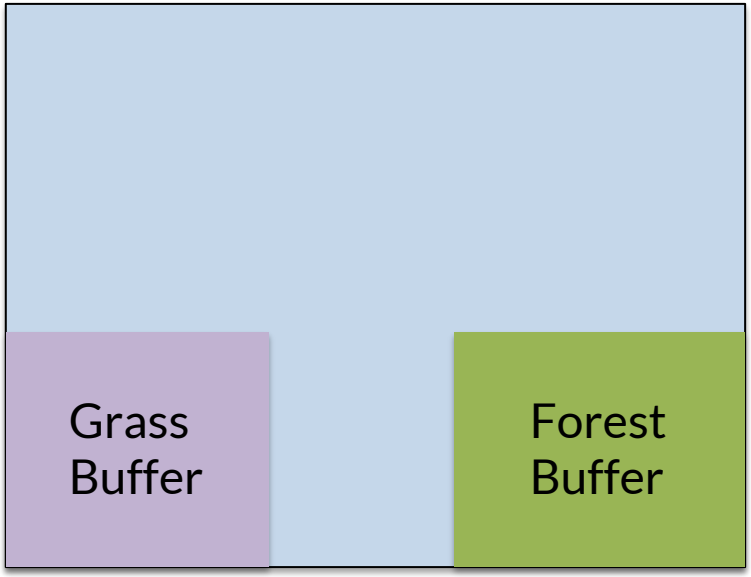
Figure modified from Rosenberg, 2015

Sub-problem formulation

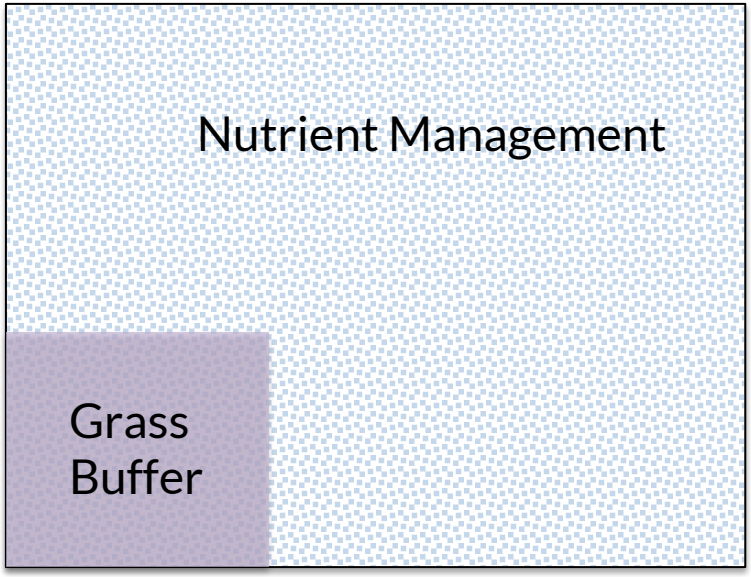
Goals of this effort:

- **Provide insight for appropriate algorithms**
- **Solve nonlinear optimization for select BMPs**

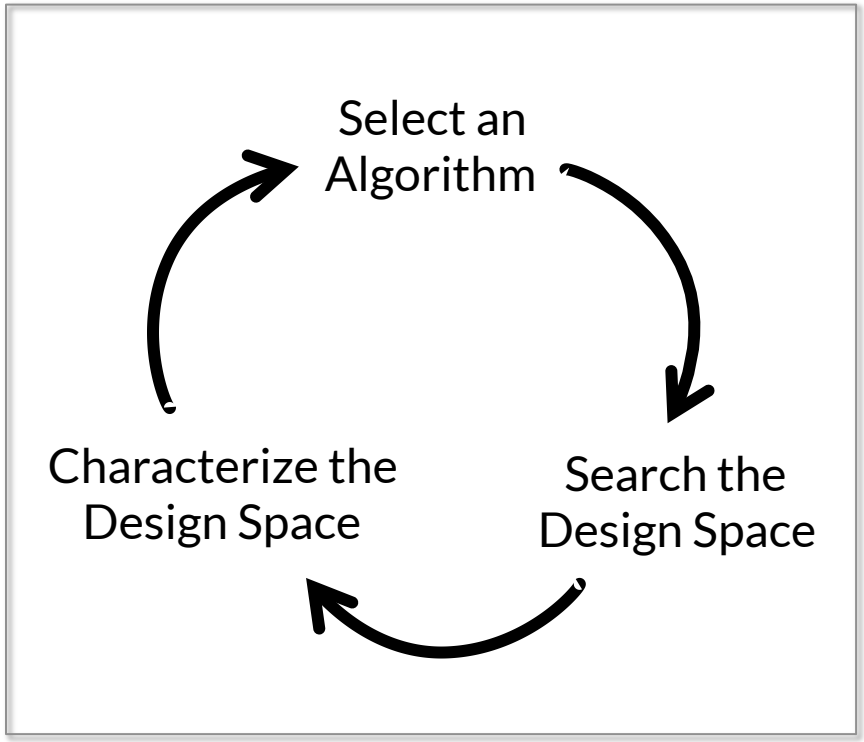
Mutually Exclusive (aka Additive)



Overlapping (aka Multiplicative)



Post Fast-CAST (Algorithms / Packages)



Various Possible Approaches

- **Population-based stochastic search**

  (e.g. Genetic algorithm)
- **Decomposing into sub-problems, with multiple algorithms**
  - *Population-based for land use change and/or manure transport*
  - *Greedy algorithm or nonlinear programming for efficiency BMPs*
- **Model training**

Figure modified from Red Cedar Tech., WP-1022

Near-term Milestones

Date	Optimization Task
Summer 2018	Analyses of sampling experiments & sub-problem formulation
End of Summer	Scenario generator interfacing with CoreCAST Beta
Fall 2018	Algorithm/package evaluation
Winter 2018	Beta testing of version 0.1, constraints & user interface

Near-term Milestones & Looking ahead

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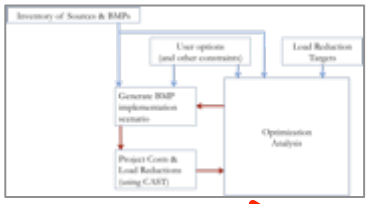
Sandbox



Identifying Alternatives

Cost Tradeoffs

Baseline Optimization Prototype

Co-benefits

Local Targets

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BMP Co-Benefits

Report and Scoring (2017)

- Impacts on **non-nutrient and non-sediment related** CBP priorities
- -5 to +5 score per BMP per priority

Management tools

- Coupling with CAST
- **Co-Benefits scores as an assessment tool** ("top down"):
  - Average of scores for all BMPs in an existing scenario
  - How to count BMPs is an issue

Content courtesy of Michelle Williams

Co-Benefits Scores as a Planning Tool ("Bottom-up" approach)

Scores are qualitative, so they don't scale with BMP implementation or combine

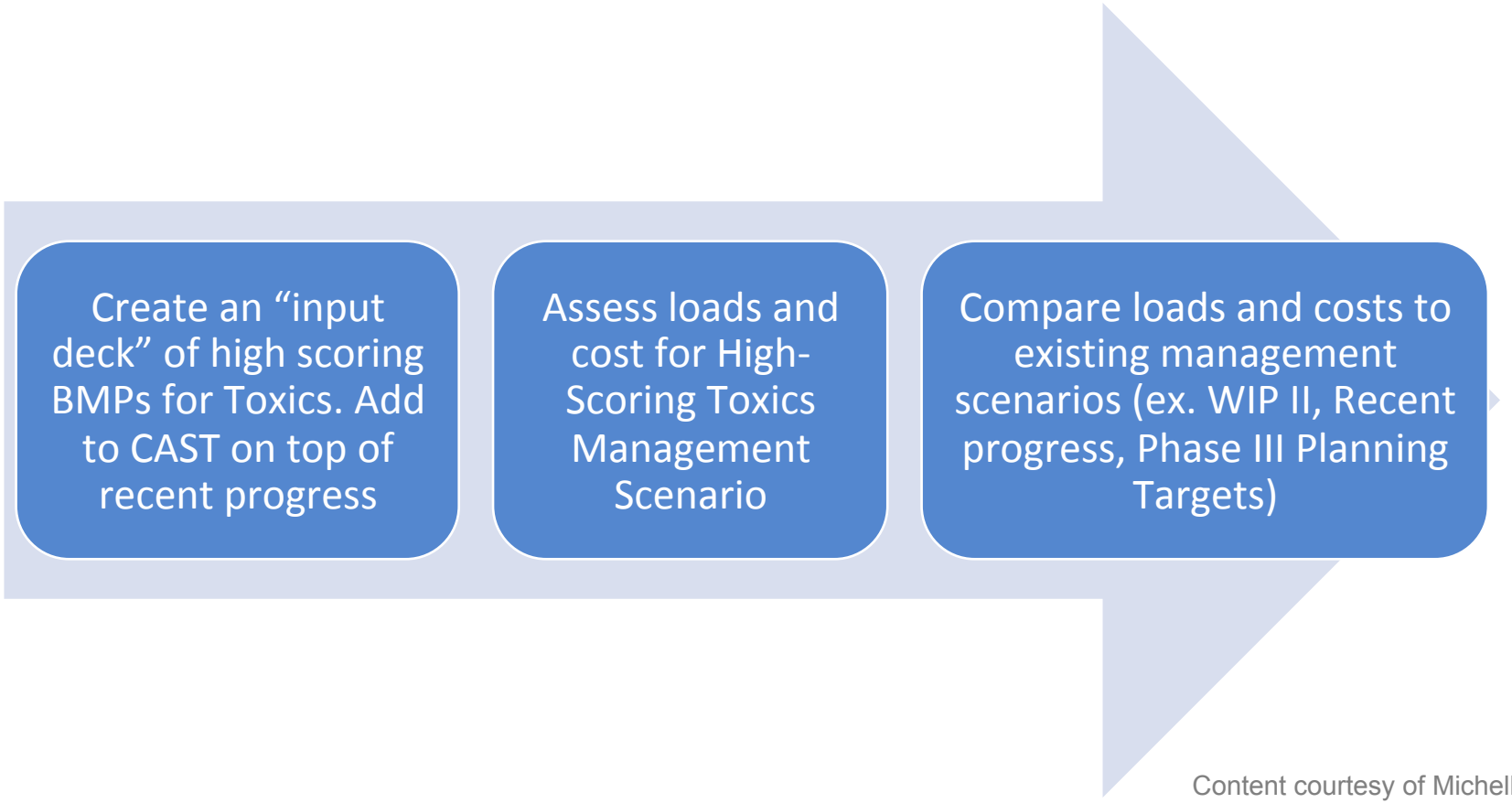
Cannot evaluate/compare scenarios without cumulative score

However, BMPs can be selected that exhibit high co-benefit scores, and these can be maximized when building N/P/S management scenarios in CAST

Content courtesy of Michelle Williams

“Bottom Up” Approach: Co-Benefits Scores as a Planning Tool

Feasibility of targeting toxic contaminants management within constraints of nutrient and sediment TMDL implementation



Content courtesy of Michelle Williams

Following the Initial Project:

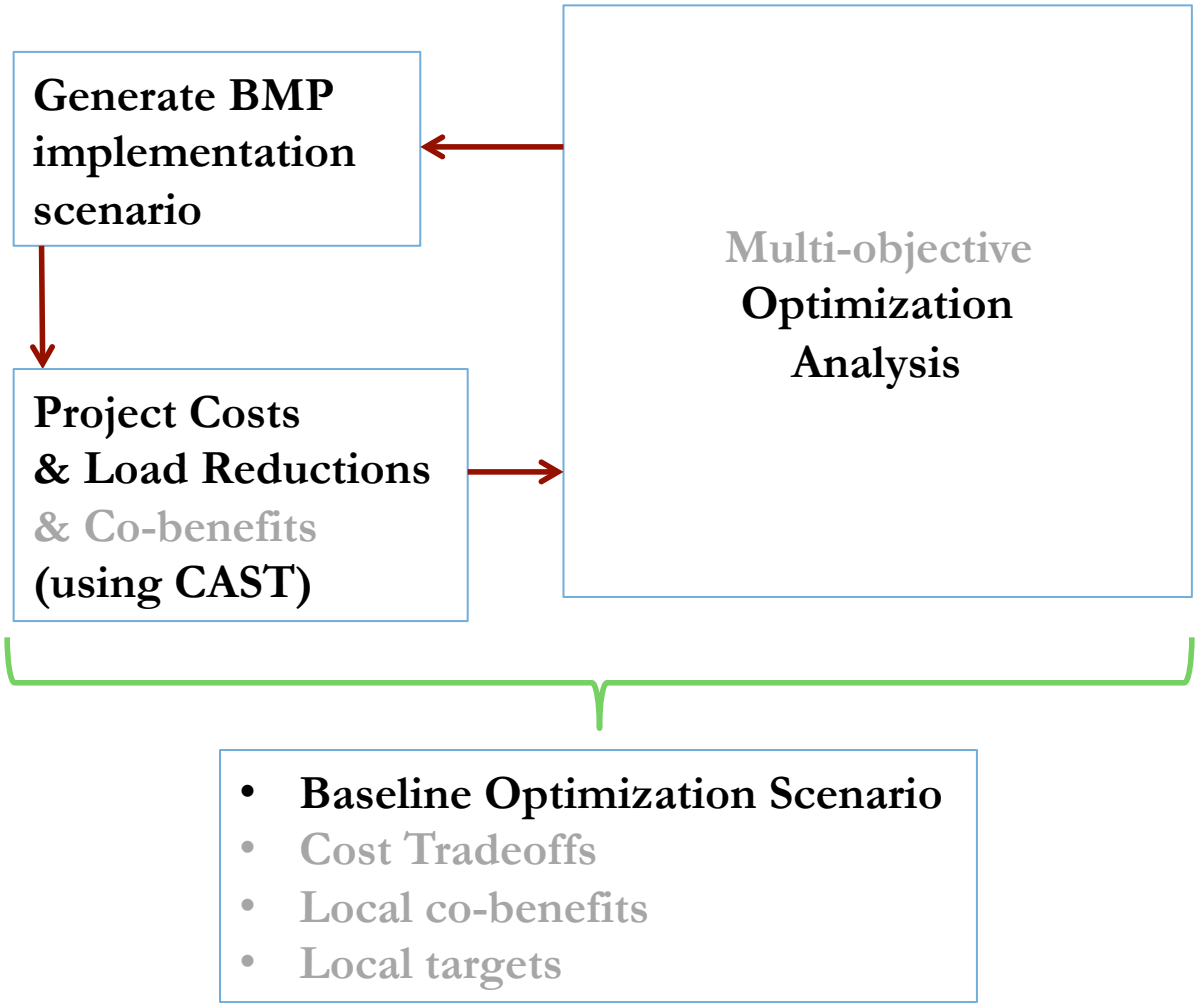
Similar analyses for all outcomes

Identify knowledge gaps for additional co-benefits use and optimization

Outreach to local managers and stakeholders:

- Does this add to existing management tools?
- Use in conducting public outreach for TMDL-related management?

Looking Ahead



Summary

Objectives:

- Minimize Cost
- Meet Nutrient Load Targets
- Maximize Co-benefits

Software design & formulation

- underway, continued updates

Sampling experiments

- beginning this month

Looking ahead

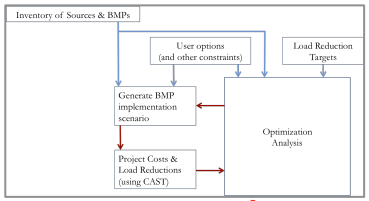
Post Fast-CAST

- algorithm/package testing

Co-benefits

- Find ways to incorporate quantitative info

Sandbox



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