

***Modeling Workgroup
Meeting Quarterly Review***

Optimization update

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MICHIGAN STATE UNIVERSITY, JAN 2023



Overview

- Objective 2: Development of Efficient Multi-objective Optimization Procedures
 - Oct 1, 2021 to September 30, 2023 (24 months)
- Up-to-date status of the project: Optimization approaches, integration with CAST, and API development
- Status of incorporation of BMPs into the optimization framework
- Interesting results through Innovization
- Conclusion and future work

Current status of the project

[illegible]

Task 2: Development of efficient multi-objective (MO) optimization procedures

2.1: Develop generative MO optimization using hybrid optimization procedure developed at Task 1

2.2: Develop simultaneous MO customized optimization using population-based evolutionary algorithms

2.3: Comparison of generative & simultaneous procedures and validation with CBP users & decision-makers

2.4: Develop an interactive multi-criterion decision-making aid for choosing a single preferred solution

Engine and Parallel Computing

3.1: Comparative study to choose a few best performing methods

3.2: Scalability to State and Watershed level Scenarios

3.3: “Innovization” approach for improving scalability

4.4: Distributed computing approach for improving scalability

Task 4: User-friendly and routine applications with enhanced optimization procedures

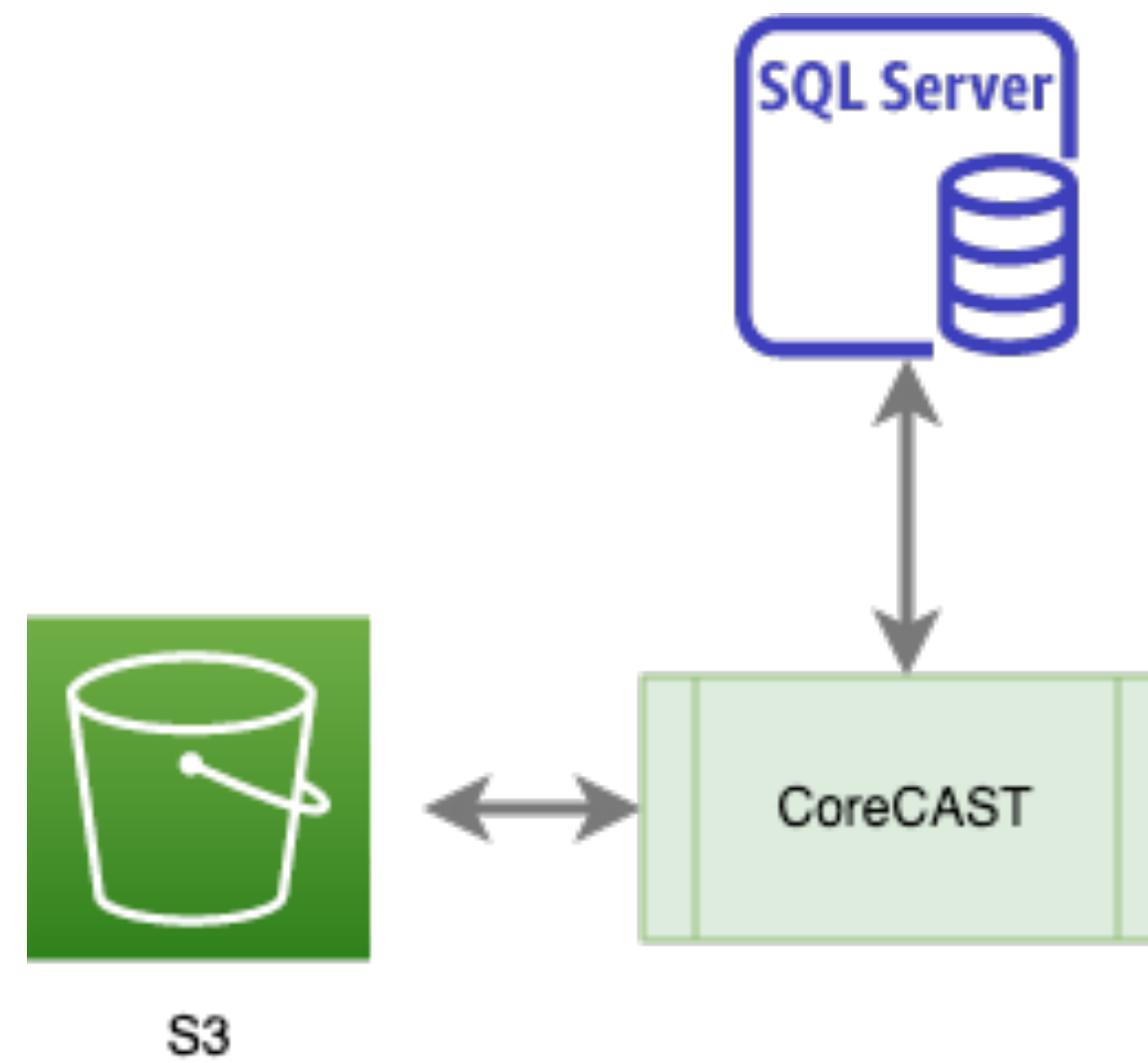
4.1: User-friendly optimization through a dashboard

4.2: Surrogate-assisted optimization procedures

4.3: Robust optimization method for handling uncertainties in variables and parameters

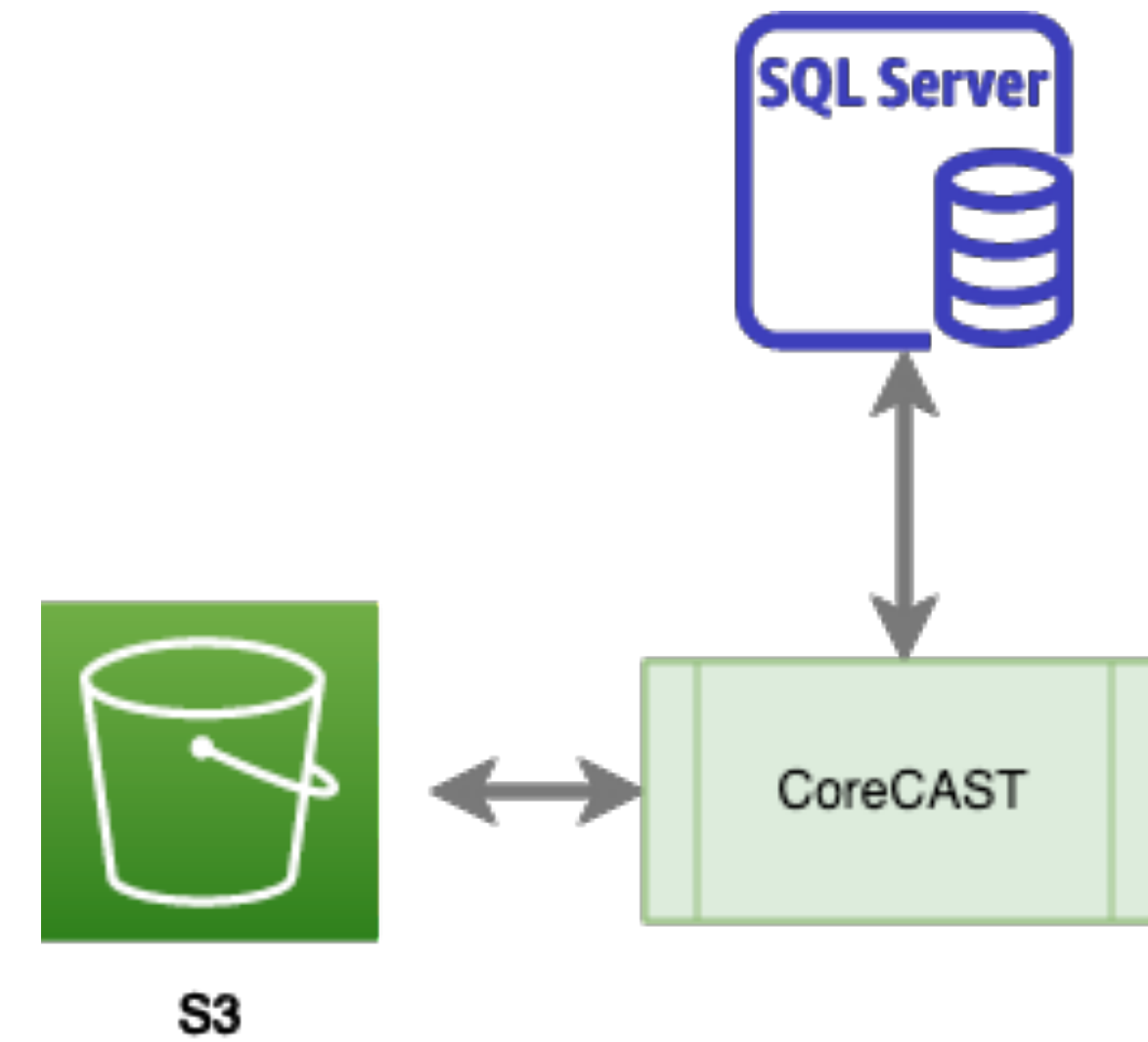
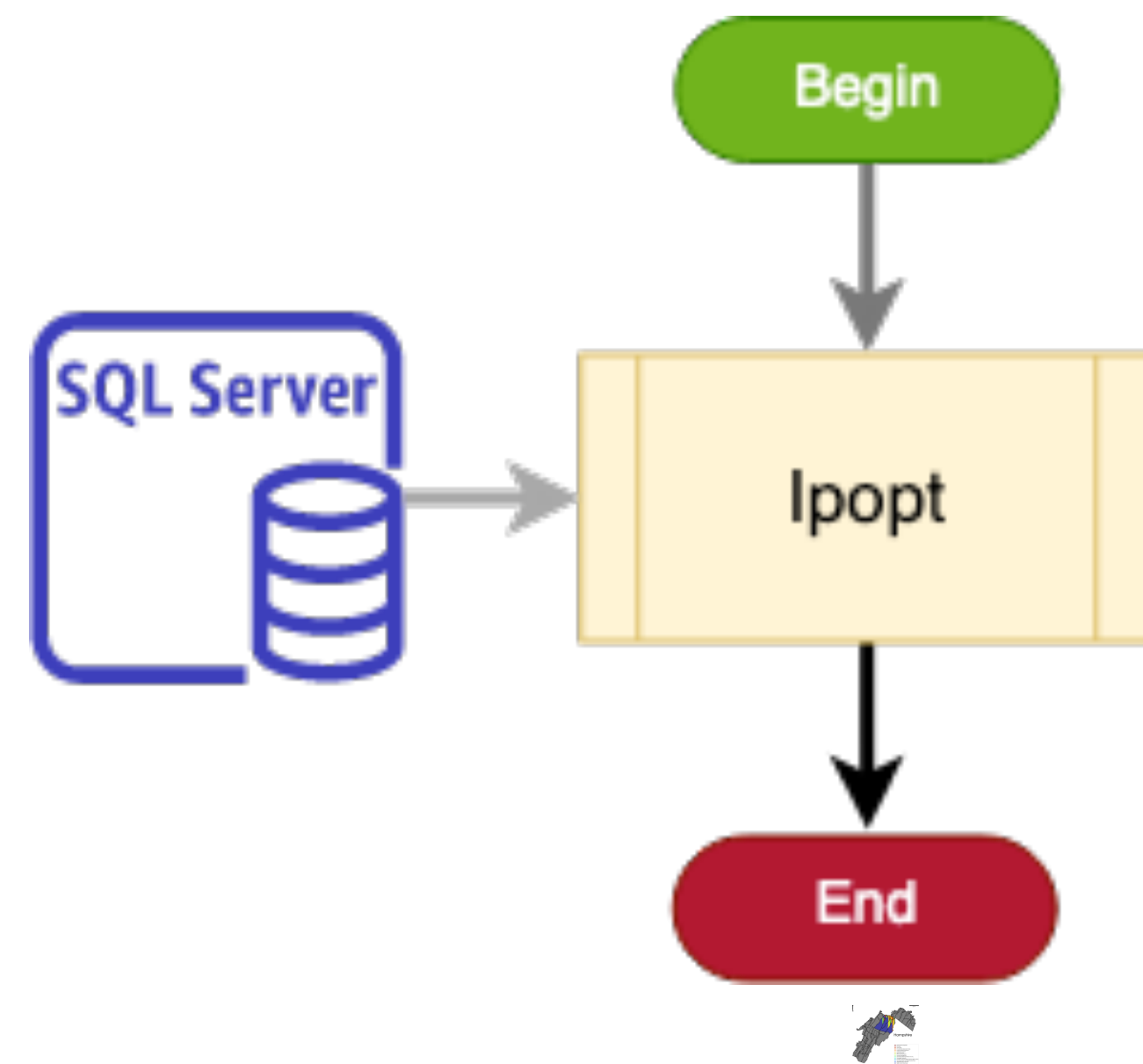
4.4: Sustainable watershed management practices

Project Progress

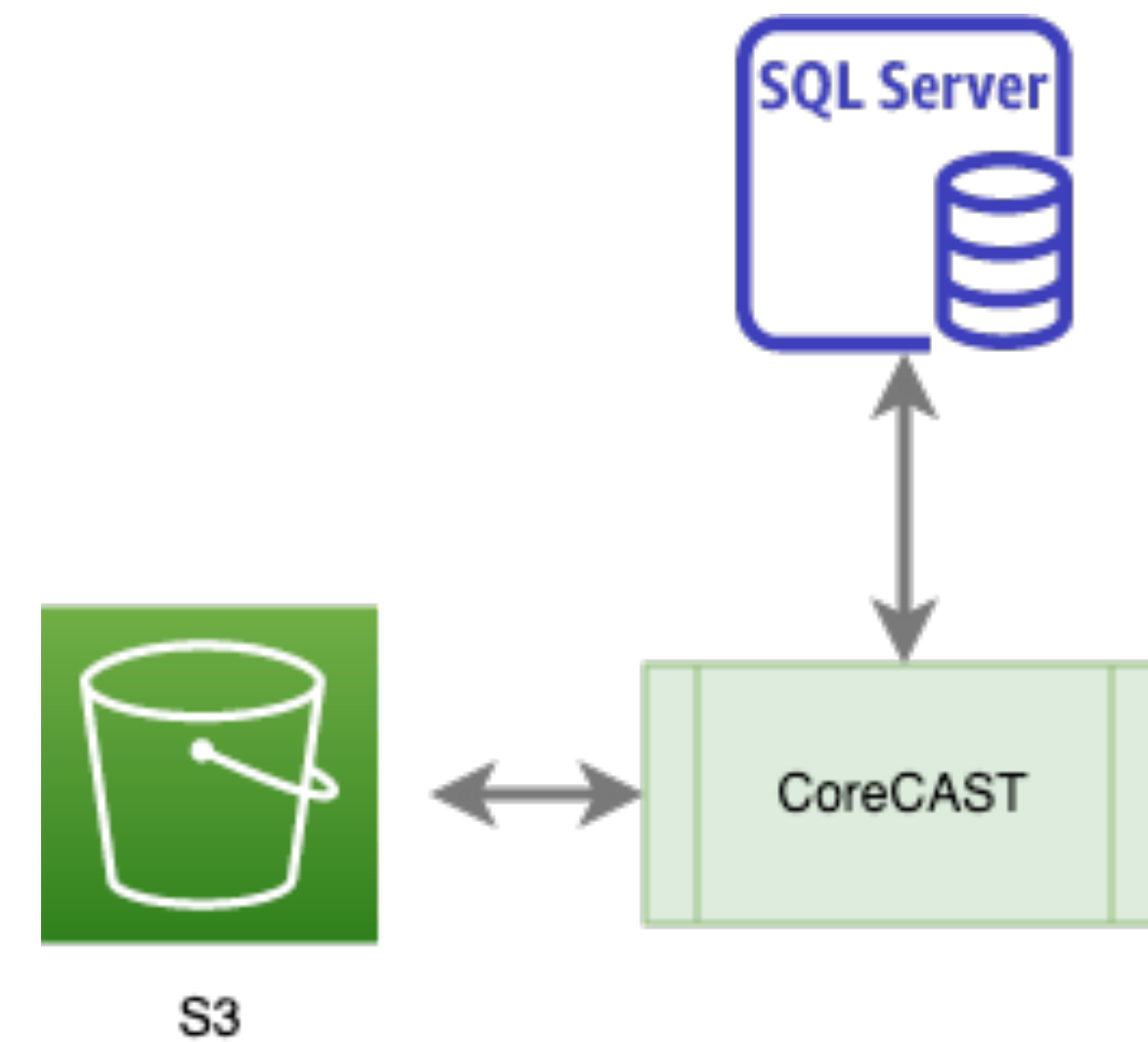
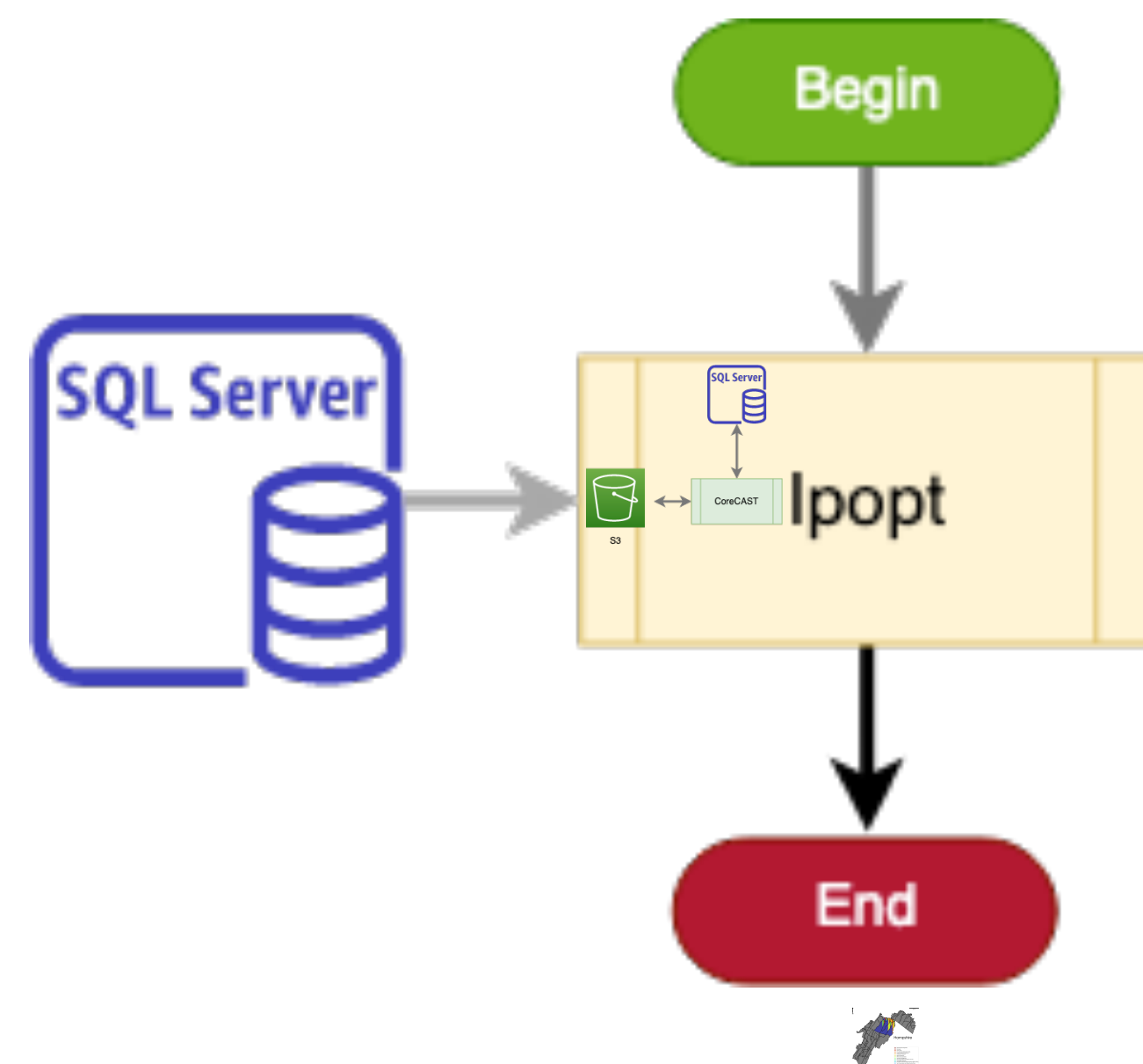


Project Progress

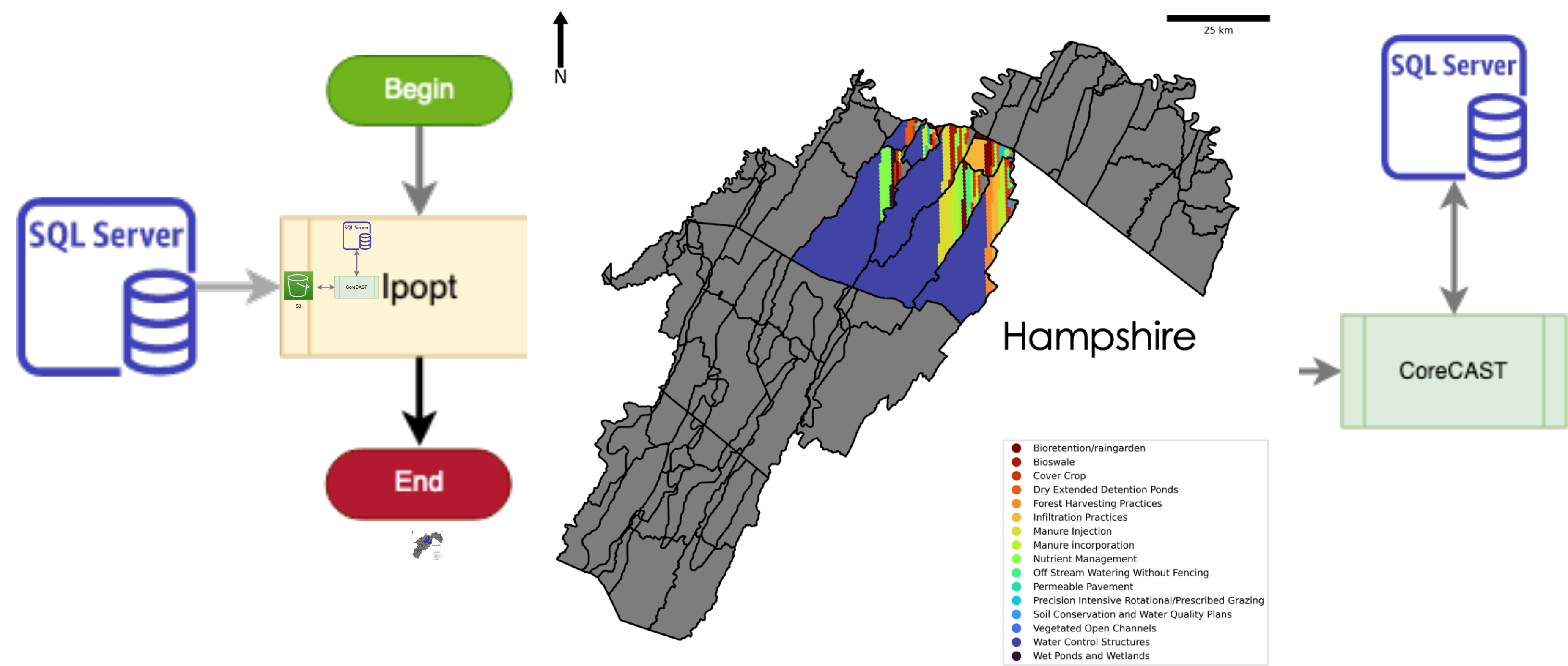
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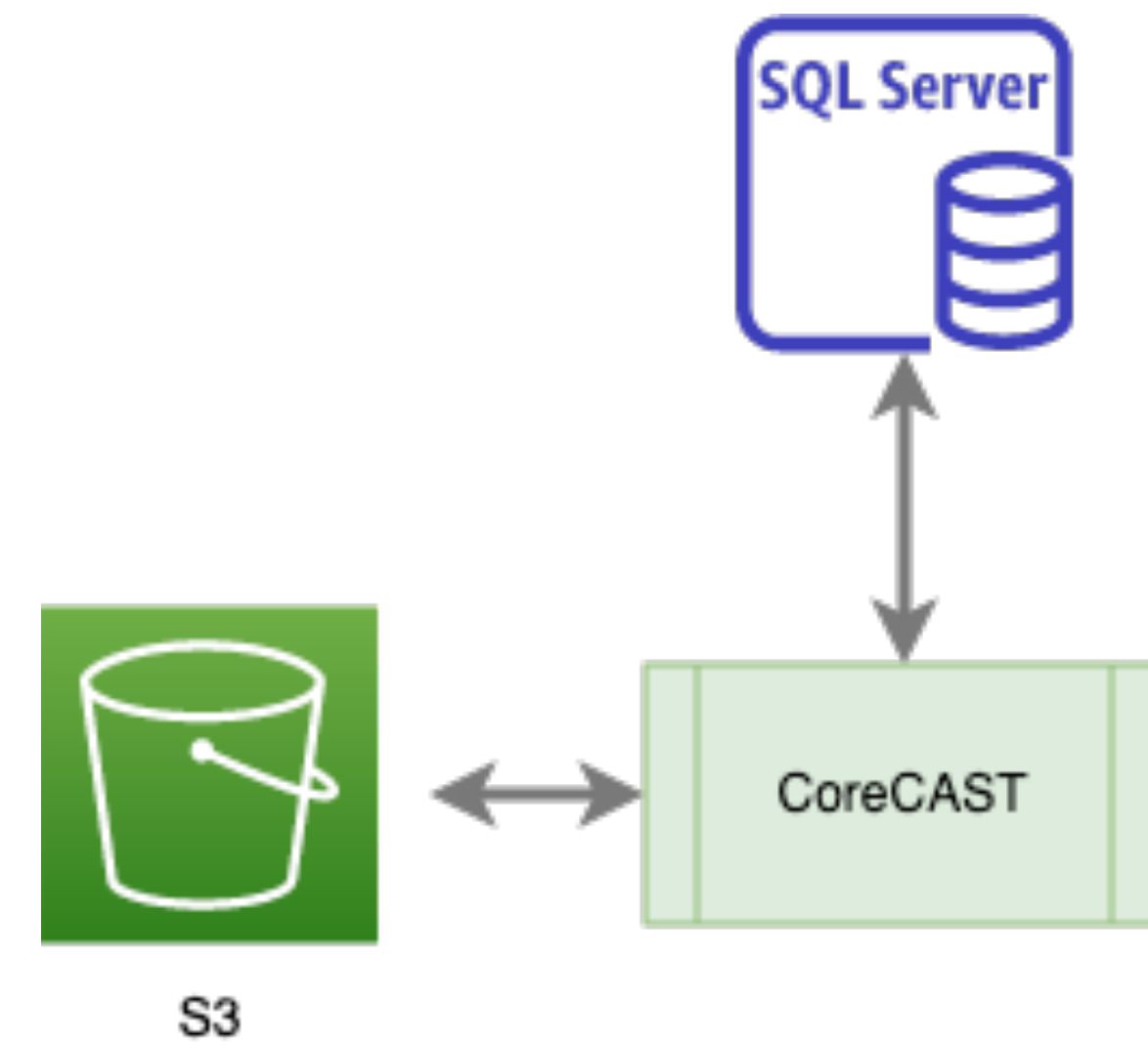
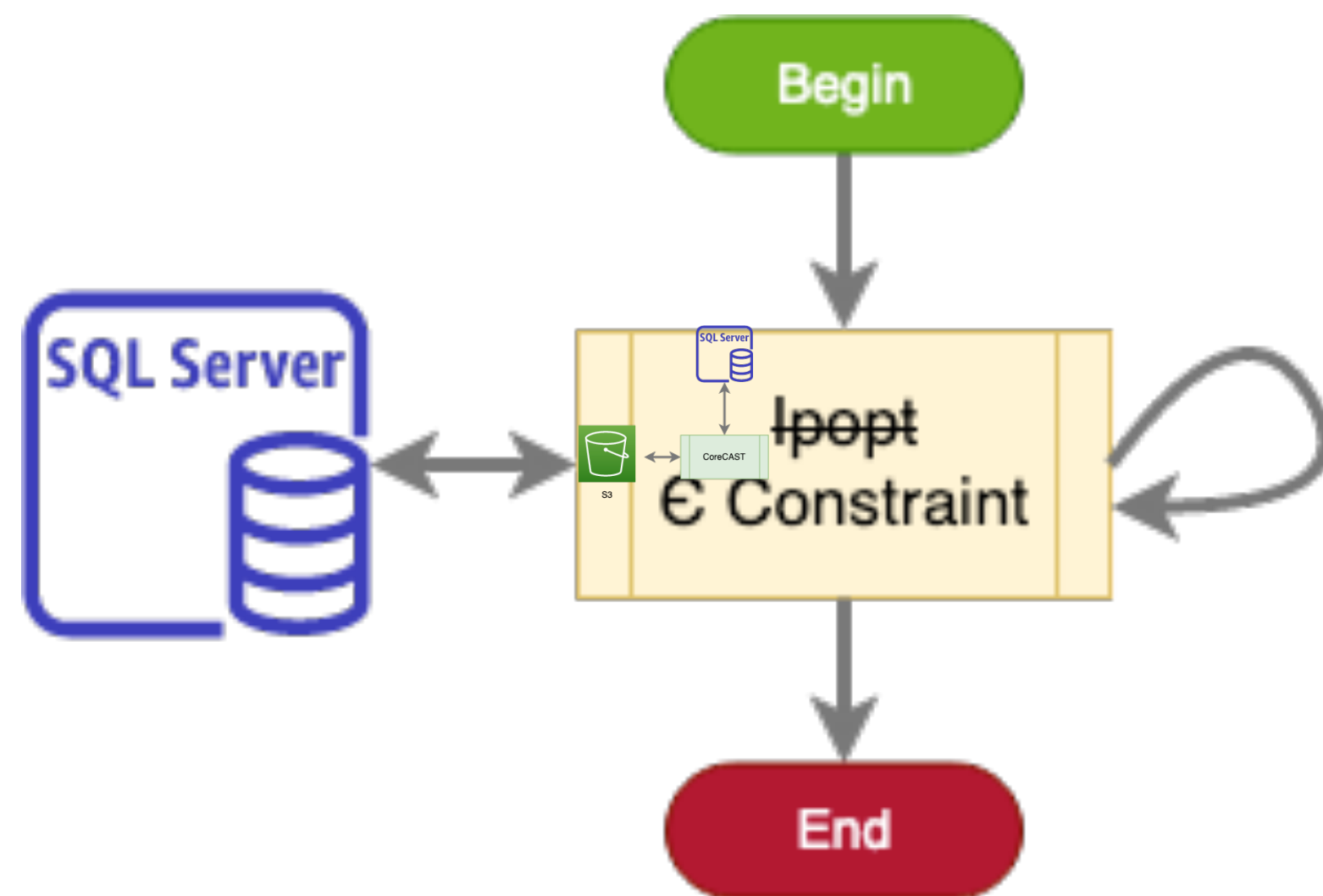
Project Progress



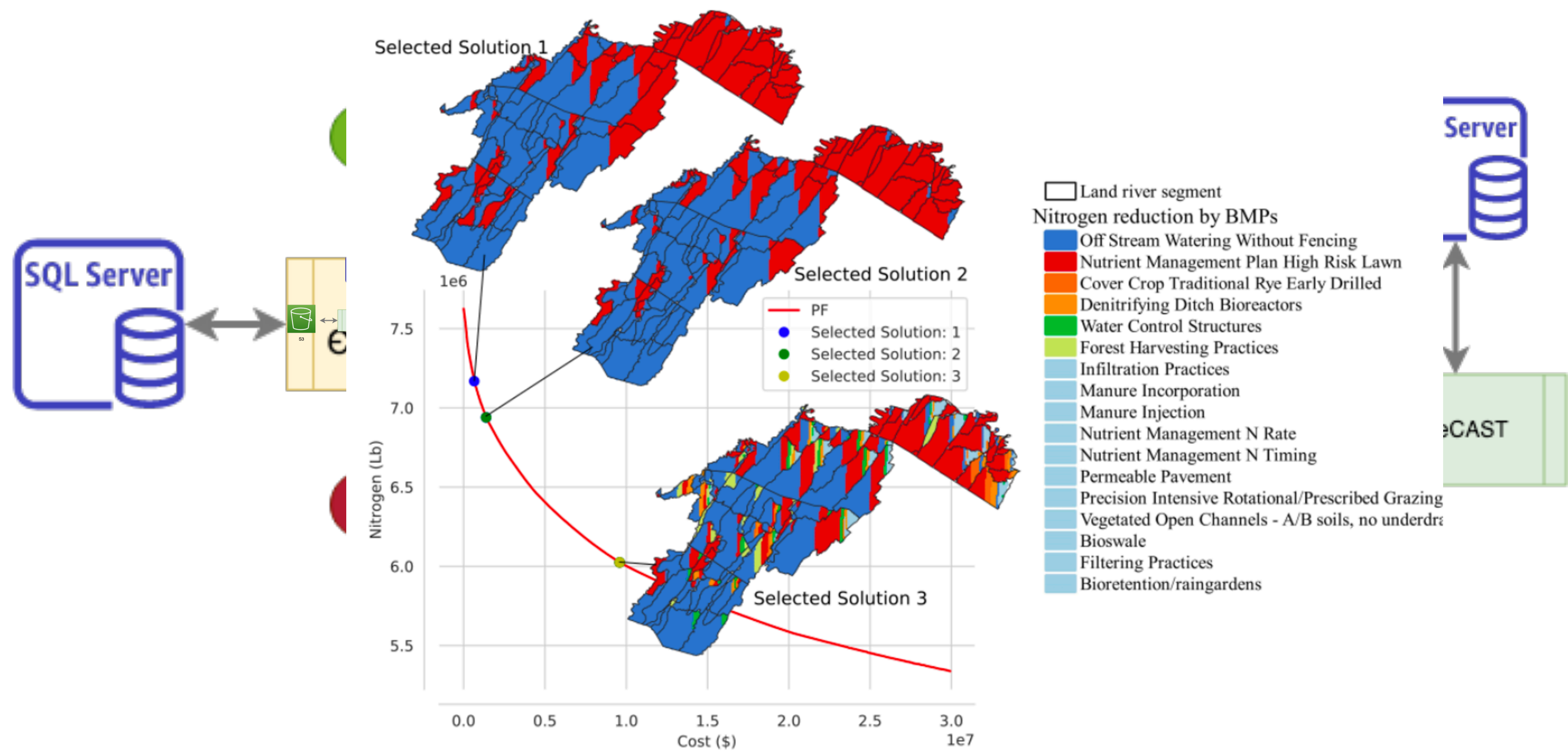
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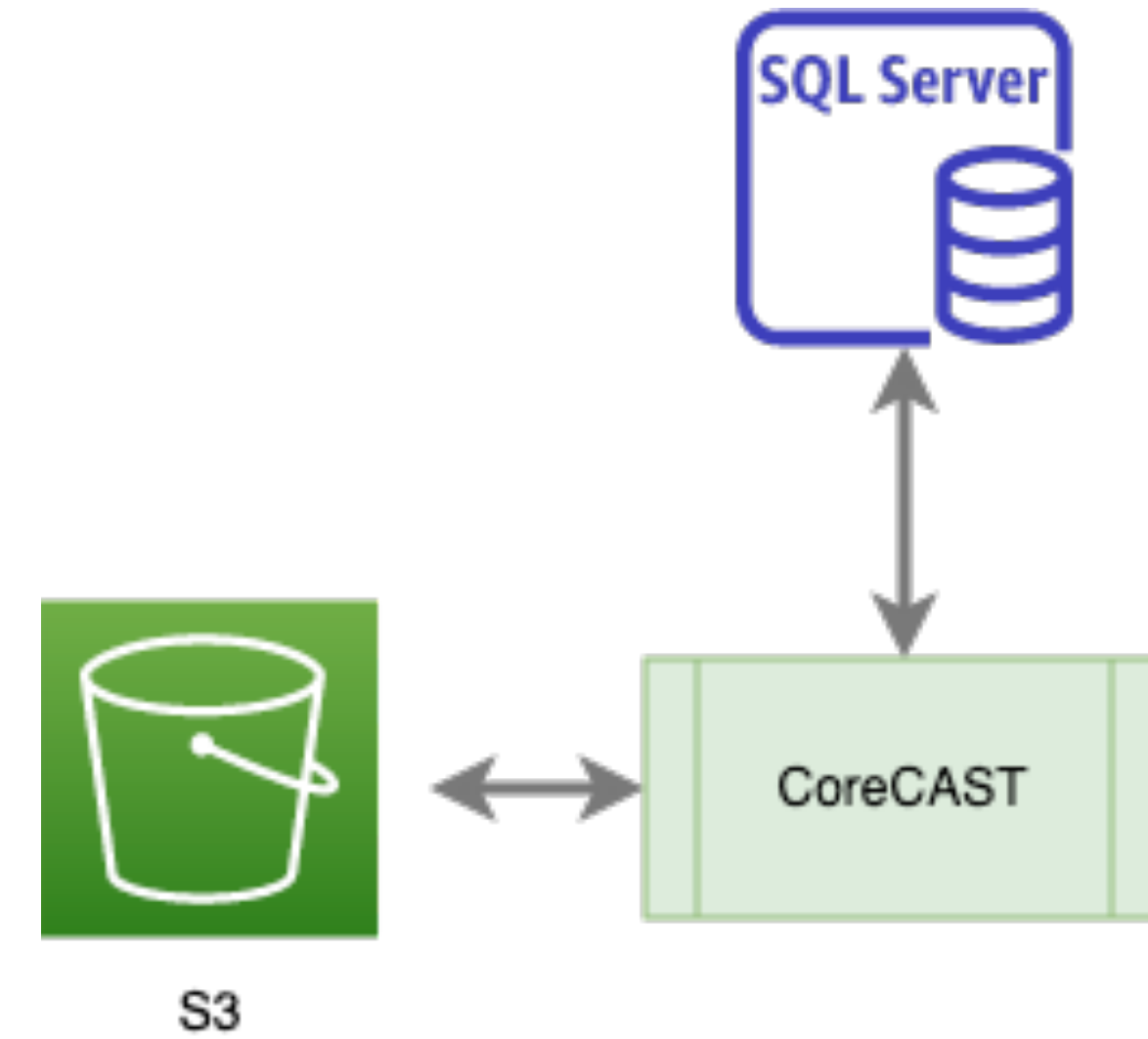
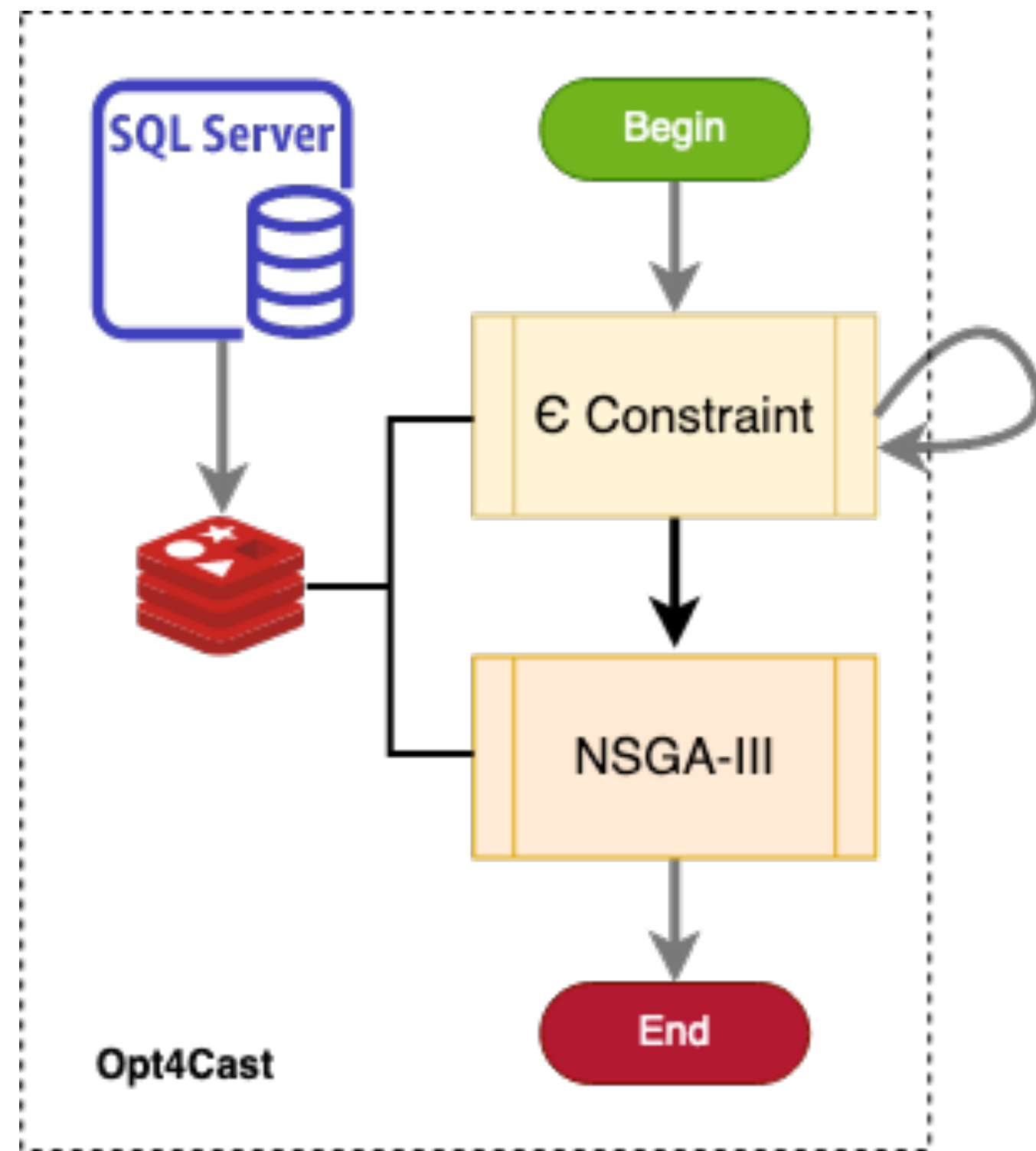
Project Progress



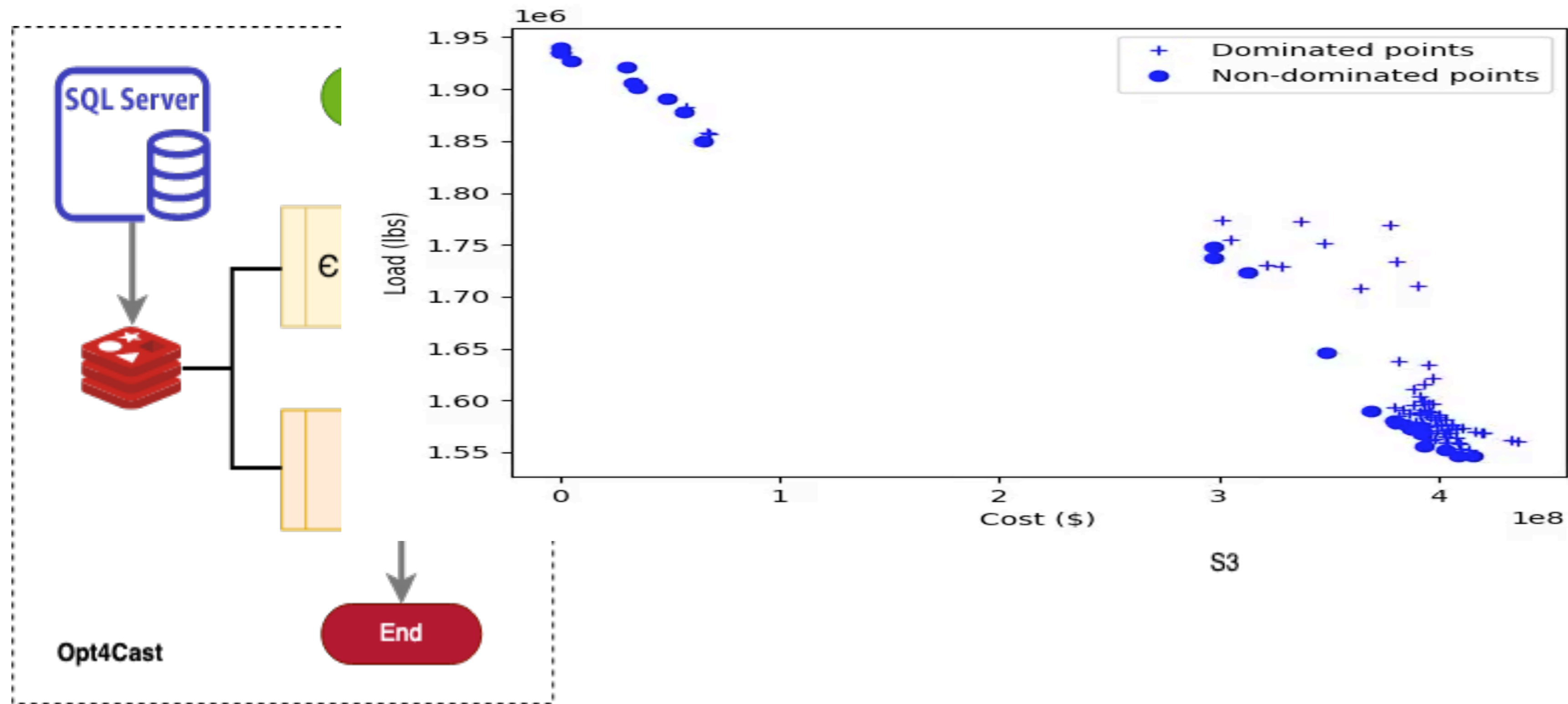
Project Progress



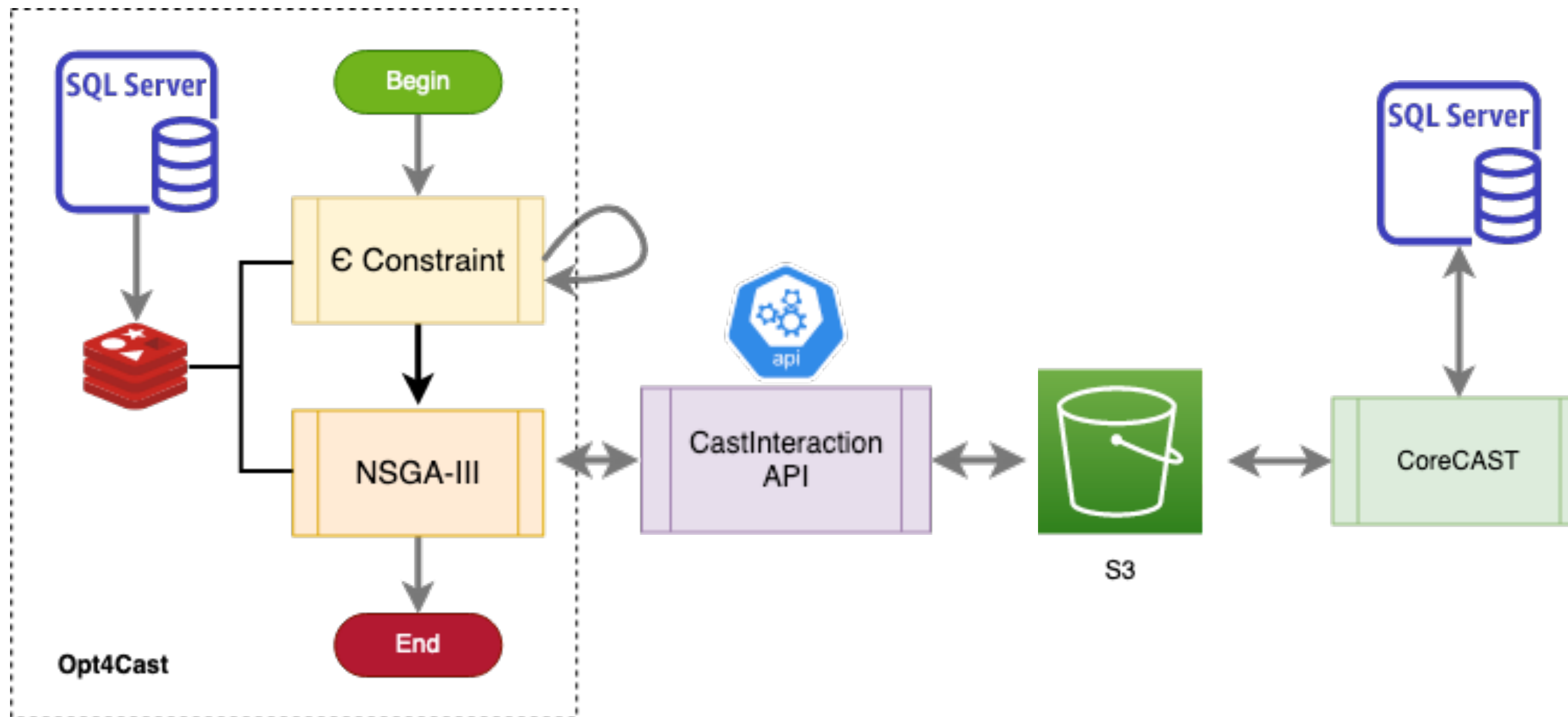
Project Progress



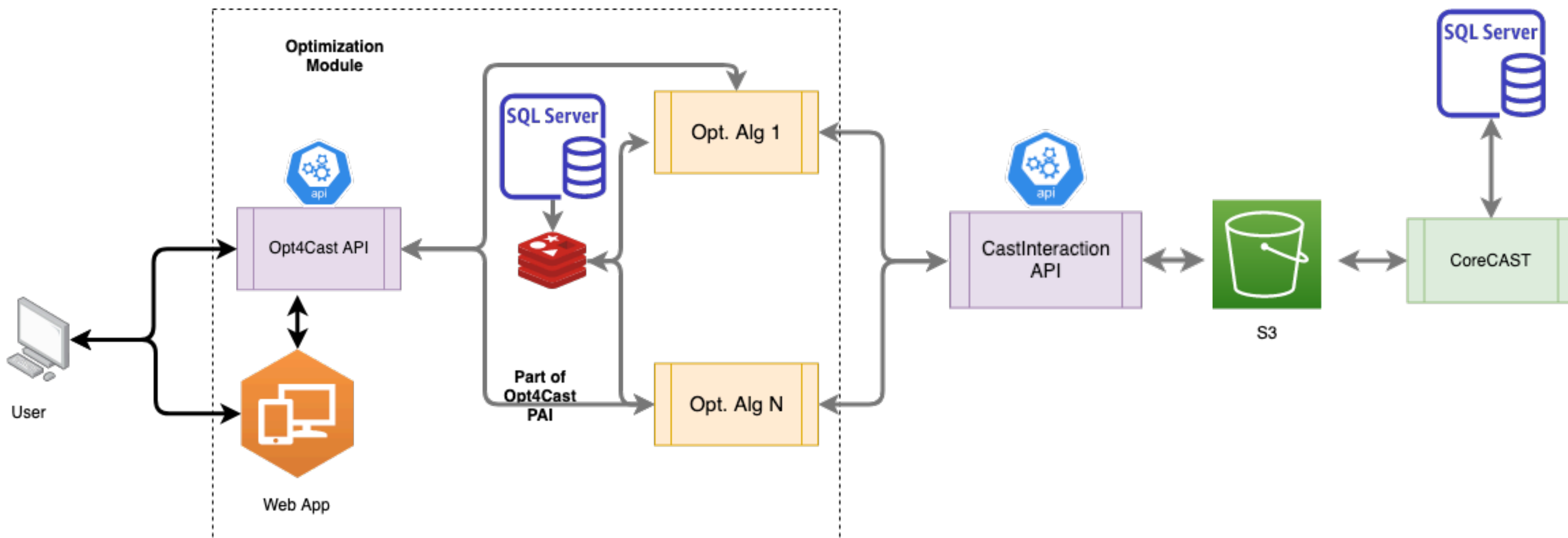
Project Progress



Project Progress



Project Progress




Project Progress

HOME

SCENARIOS

HELP



GREGORIO

1

2

3

4

5

6

Scenario Info

Loads

BMP Selection

Update Costs

BMP Constraint

BMP Constraint Advanced

BMP Constraint (Advanced)

Add your preferences:

Developed

Septic

Natural

Manure Treatment

Animal

Land Conversion

Agriculture

Animal BMPs

BMP

Animal Waste Management System

UNIT

animal unit

ANIMAL GROUP

beef

LOAD SOURCE

Permitted Feeding Space

LOWER BOUND

5

animal unit

UPPER BOUND

10

animal unit

Add

#	BMP	Animal Group	Load Source	Lower Bound	Upper Bound
1	Animal Waste Management System	beef	Permitted Feeding Space	5	10

PREVIOUS

OPTIMIZE

Load (million lbs)

Cost (million \$)

● NSGA-III + CoreCAST + eps_cnstr
● Base Scenario, No BMP implementation

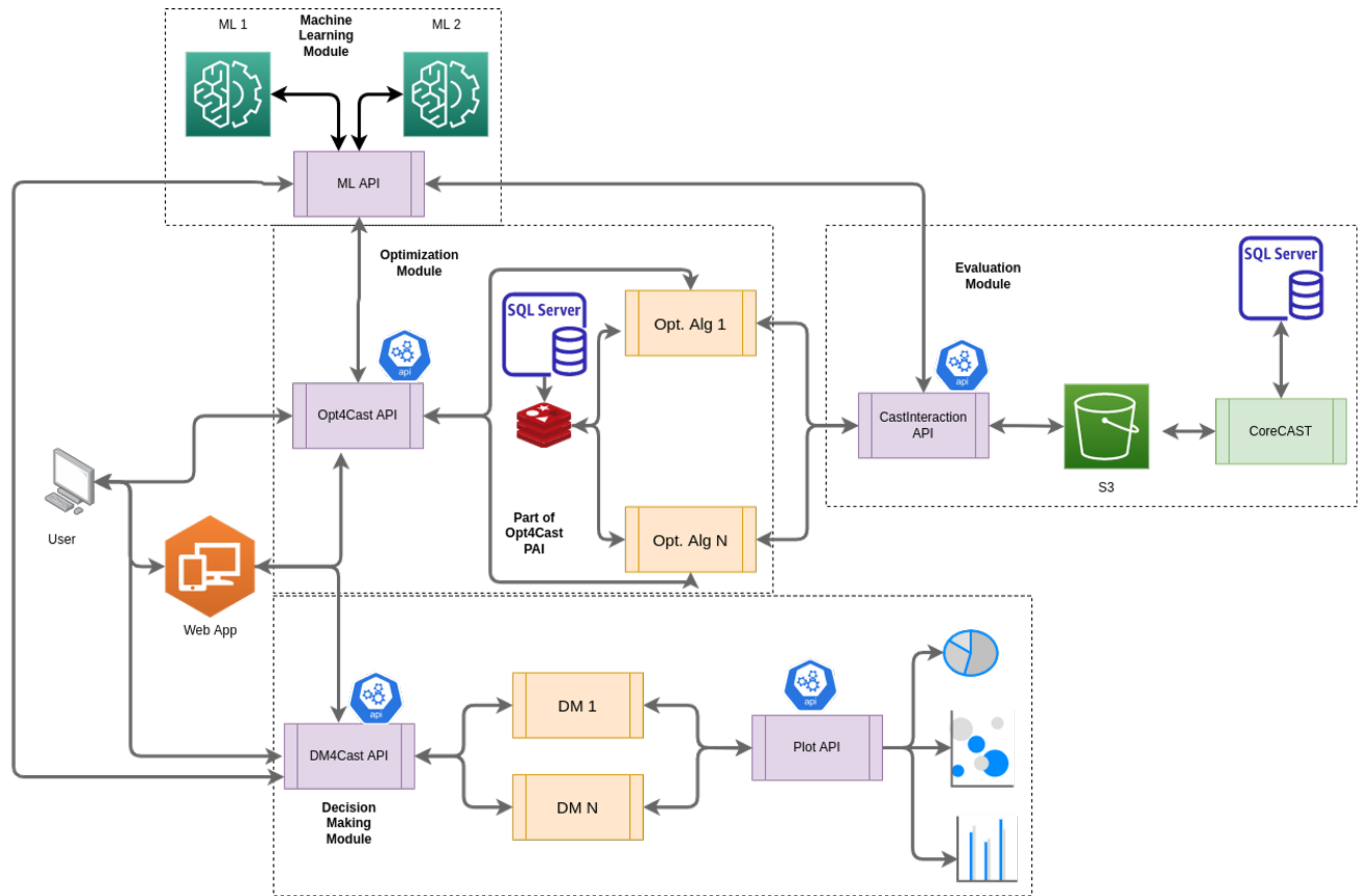
Cost (million \$)	Load (million lbs)	Scenario
0.5	30.5	Base Scenario, No BMP implementation
0.8	29.8	NSGA-III + CoreCAST + eps_cnstr
1.2	29.0	NSGA-III + CoreCAST + eps_cnstr
1.8	28.3	NSGA-III + CoreCAST + eps_cnstr
2.5	27.6	NSGA-III + CoreCAST + eps_cnstr
3.5	26.9	NSGA-III + CoreCAST + eps_cnstr
4.5	26.1	NSGA-III + CoreCAST + eps_cnstr
5.5	25.6	NSGA-III + CoreCAST + eps_cnstr
6.5	25.5	NSGA-III + CoreCAST + eps_cnstr
7.5	25.3	NSGA-III + CoreCAST + eps_cnstr
8.5	24.7	NSGA-III + CoreCAST + eps_cnstr
9.5	24.2	NSGA-III + CoreCAST + eps_cnstr
10.5	23.8	NSGA-III + CoreCAST + eps_cnstr
11.5	23.5	NSGA-III + CoreCAST + eps_cnstr
12.5	22.8	NSGA-III + CoreCAST + eps_cnstr
14.0	21.5	NSGA-III + CoreCAST + eps_cnstr

25 km

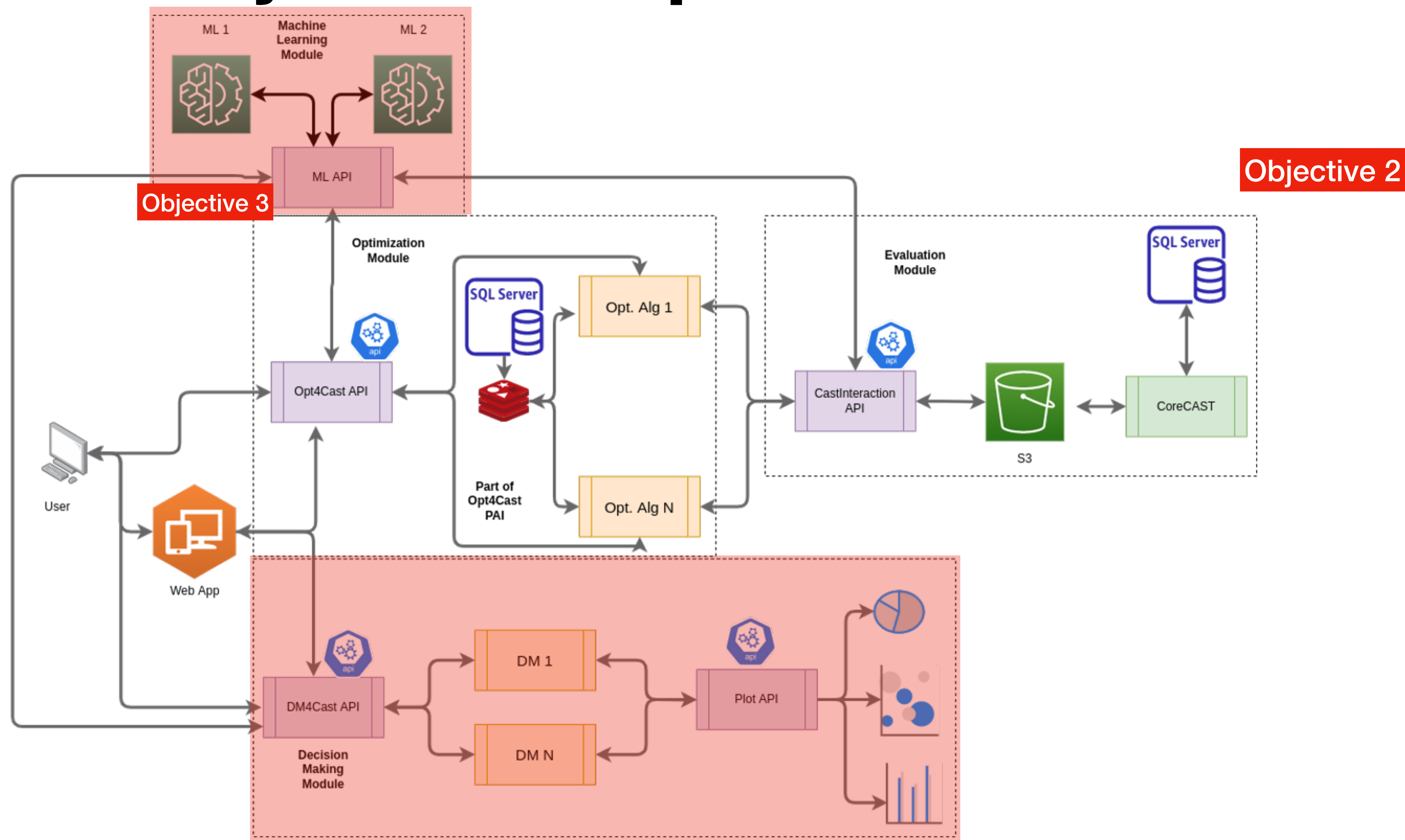
N

- Bioretention/raingarden
- Bioswale
- Cover Crop
- Dry Detention Ponds and Hydrodynamic Structures
- Dry Extended Detention Ponds
- Filter Strip Runoff Reduction
- Filtering Practices
- Forest Harvesting Practices
- Impervious Disconnection to amended soils
- Infiltration Practices
- Manure Injection
- Manure incorporation
- Nutrient Management
- Off Stream Watering Without Fencing
- Permeable Pavement
- Precision Intensive Rotational/Prescribed Grazing
- Soil Conservation and Water Quality Plans
- Vegetated Open Channels
- Water Control Structures
- Wet Ponds and Wetlands

Projected Project Development



Projected Project Development



Curl Cont



Tested with Python, R, C++, Julia, and Go

*John Massley

Status of incorporation of BMPs into the optimization framework*


We have completed with the incorporation of BMPs into the optimization framework*. It is worth noting that our framework accepts the users' preferences, so that they establish preferences for our BMPs.

- Efficiency: 205 BMPs..
- Land Conversion: 24 BMPs.
- Animal: 5 BMPs.
- Manure Transport: 21 BMPs.

HOME

SCENARIOS

HELP



GREGORIO

1

2

3

4

5

6

Scenario Info

Loads

BMP Selection

Update Costs

BMP Constraint

BMP Constraint Advanced

BMP Constraint (Advanced)

Add your preferences:

Developed

Septic

Natural

Manure Treatment

Animal

Land Conversion

Agriculture

Animal BMPs

BMP

Animal Waste Management System

UNIT

animal unit

ANIMAL GROUP

beef

LOAD SOURCE

Permitted Feeding Space

LOWER BOUND

5

animal unit

UPPER BOUND

10

animal unit

Add

#	BMP	Animal Group	Load Source	Lower Bound	Upper Bound
1	Animal Waste Management System	beef	Permitted Feeding Space	5	10

PREVIOUS

***Rajendra Bojja**
***Jessica Rigelman**

Other uses for optimization?

What are the benefits of optimization?

- Identify the **best solutions** for the problem at hand.
- **Generate knowledge** to solve future problems.

Innovization Analysis

- **What is innovization?**

Learning from optimization results and introducing new ideas, products, and services different from the existing ones.

What Innovization can do to CBPO?

- Provide information for better decision-making for BMP selections (**farmers**)
- Identify the high priority areas for BMP implementation (**regulators**)
- Help with resources allocation (**policymakers**)

Innovization Experiment

BMP Selection ranking methodology based on Land use

- **Overall goal:** learn from optimization results to:

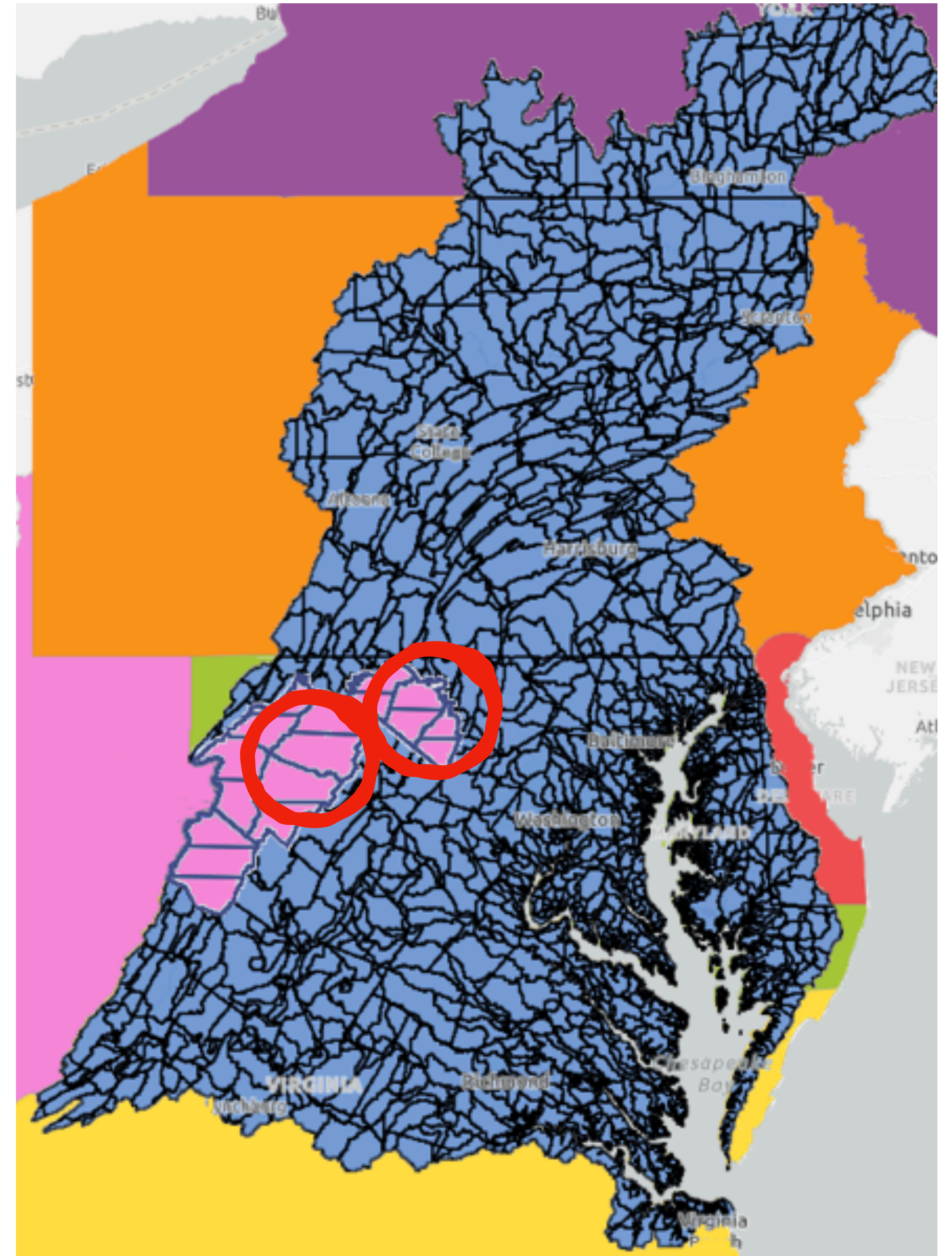
- A. Examine different ranking methodologies to **identify the top BMPs**,
- B. Identify the **similarities and differences** between top-ranked BMPs,
- C. Provide recommendations to **improve the optimization process**.

Innovization experiment

BMP Selection ranking methodology based on Land use

In **West Virginia**, we identified the top two counties with the highest areas of urban and agricultural land uses.

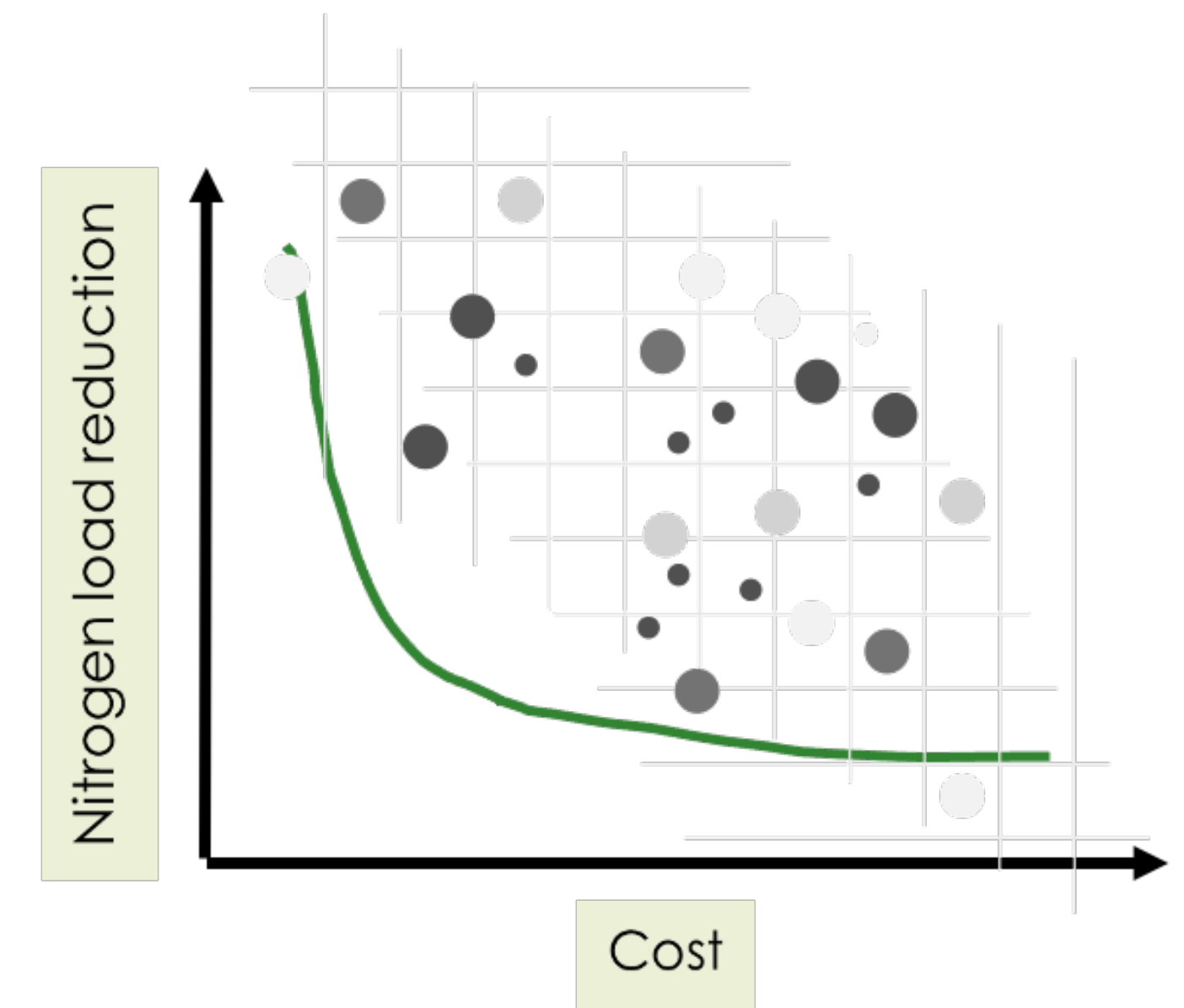
- (Berkeley and Mineral): Urban dominated
- (Jefferson and Hardy): Agricultural dominated



Innovization Experiment

BMP Selection ranking methodology based on Land use

- We performed 11 runs of our CoreCAST-optimization algorithm.
- Each run evaluated 3,000 scenarios (1,000 scenarios epsilon constraint +. 2000 scenarios NSGA-III)
- The output solution of each execution consists of 20 solutions.
- We gathered all 220 solutions (from the 11 runs)
- We filtered the solutions regarding non-dominance layers
- We performed clustering of the Pareto front.
- Identified the **best solutions from optimization.**



Methodology

BMP Selection ranking methodology based on Land use

Three ranking strategies from the combined Pareto front:

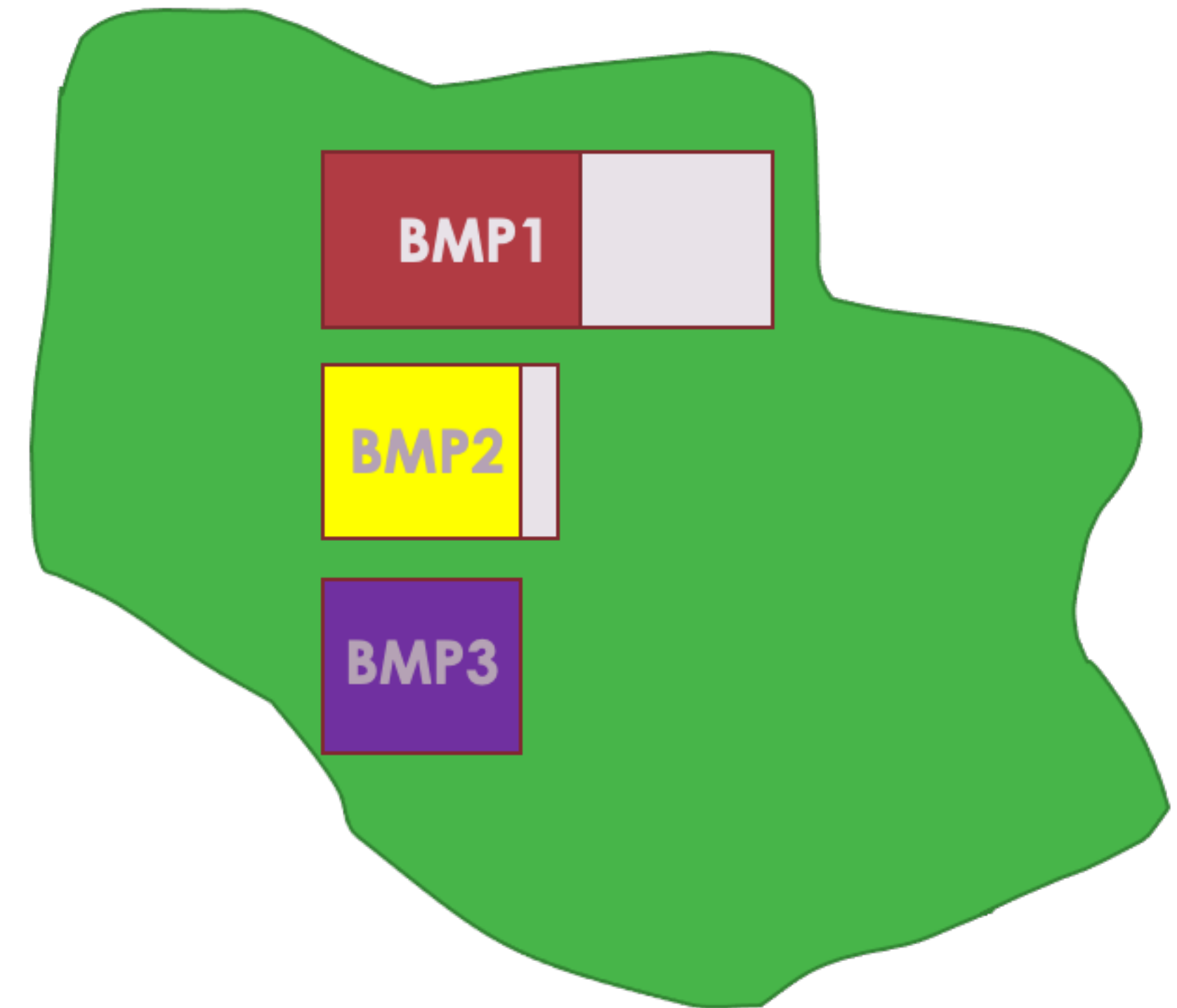
- **Strategy 1:** Rank the top BMPs based on the **implementation acreages**;
- **Strategy 2:**
- **Strategy 3:**

Ranking methodology 1:

BMP1

BMP2

BMP3



Methodology

BMP Selection ranking methodology based on Land use

Three ranking strategies from the combined Pareto front:

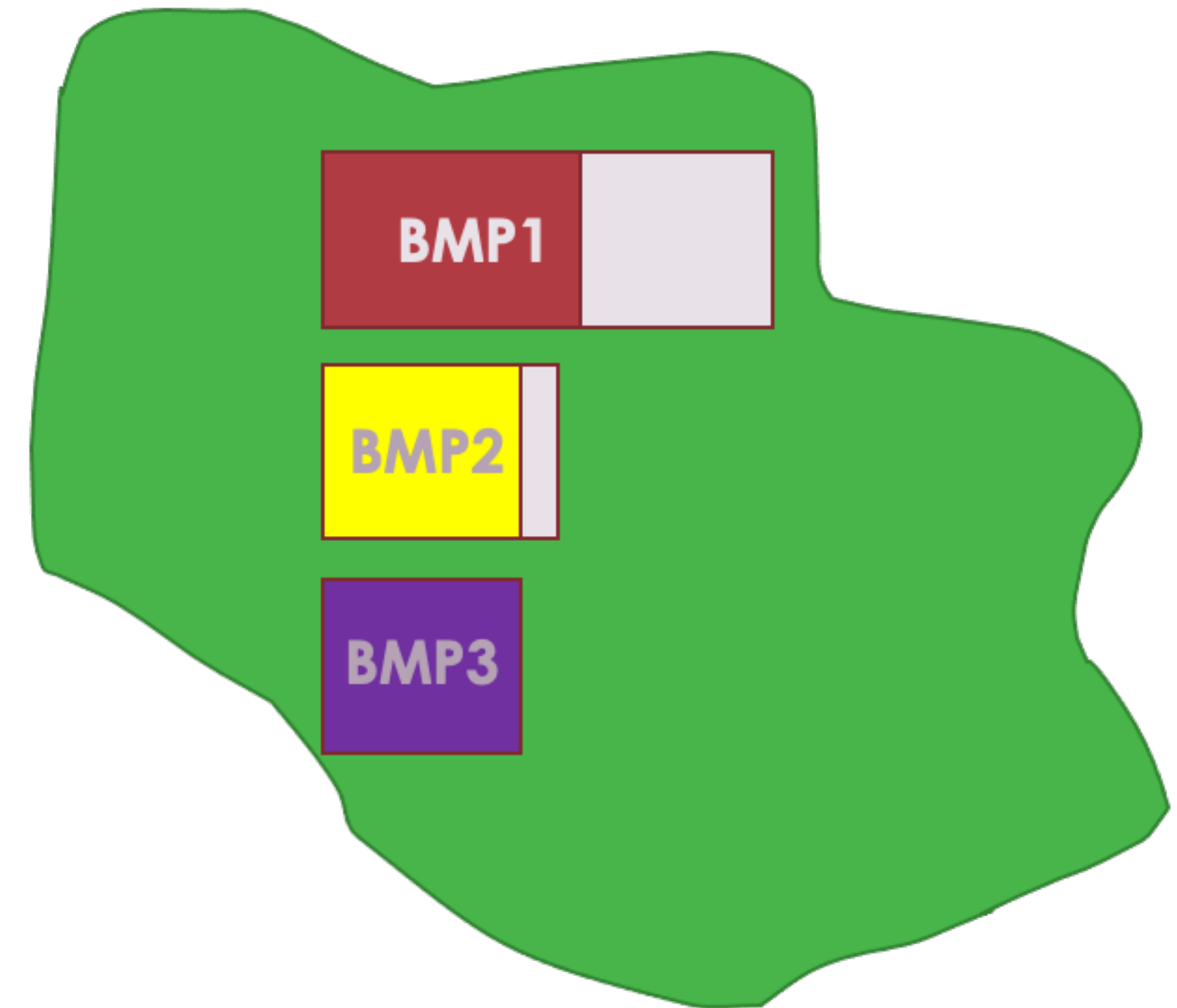
- **Strategy 1:**
- **Strategy 2:** Rank the top BMPs based on the percentage of **maximum allowable acreages**;
- **Strategy 3:**

Ranking methodology 2:

BMP3

BMP2

BMP1

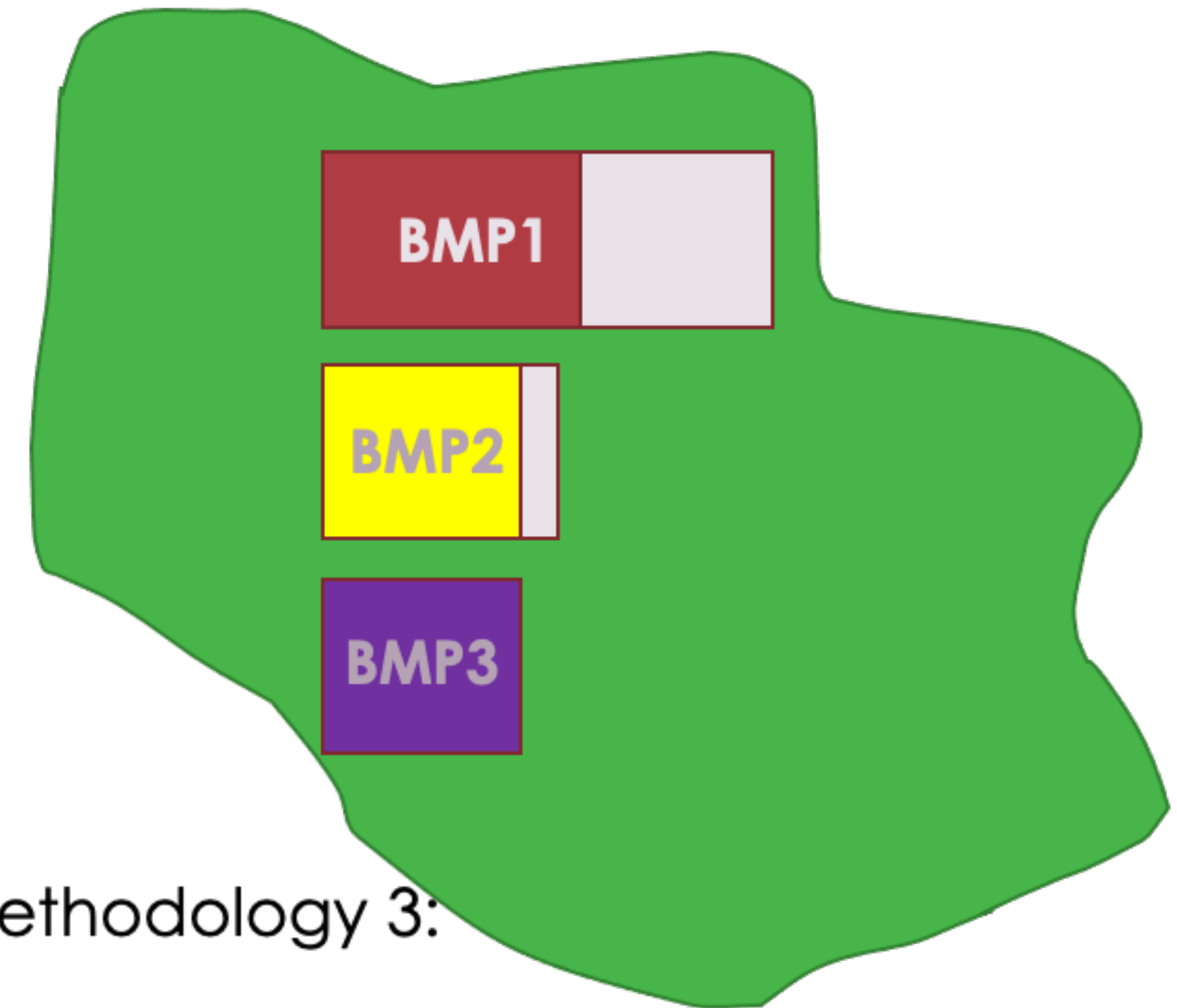


Methodology

BMP Selection ranking methodology based on Land use

Three ranking strategies from the combined Pareto front:

- **Strategy 1:**
- **Strategy 2:**
- **Strategy 3:** Rank the top BMPs based on the amount of **nitrogen reduction per dollar spent.**



Ranking methodology 3:

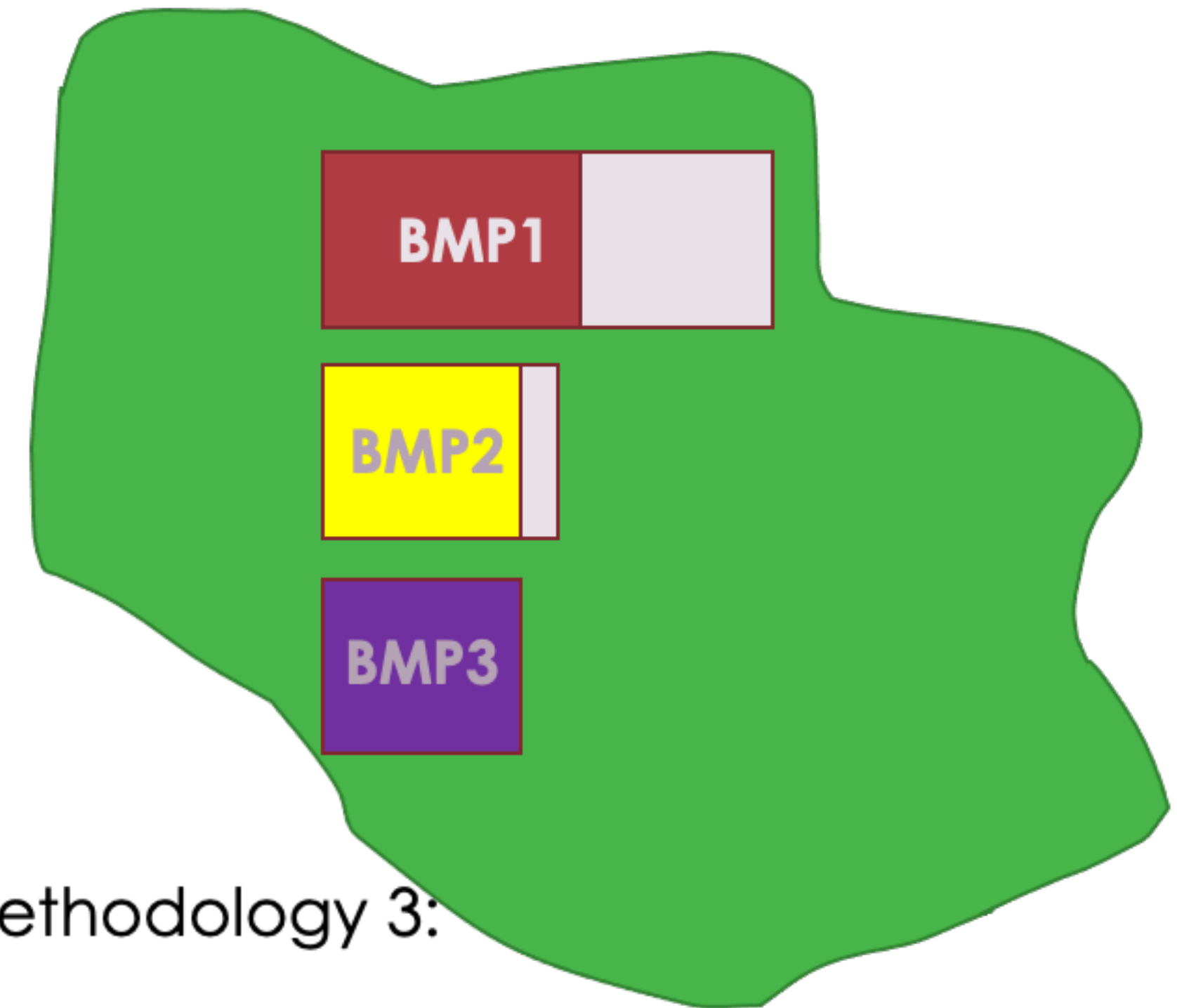
BMP2 (\$12/lb N)
BMP3 (\$15/lb N)
BMP1 (\$24/lb N)

Methodology

BMP Selection ranking methodology based on Land use

Three ranking strategies from the combined Pareto front:

- **Strategy 1:** Rank the top BMPs based on the **implementation acreages**;
- **Strategy 2:** Rank the top BMPs based on the percentage of **maximum allowable acreages**;
- **Strategy 3:** Rank the top BMPs based on the amount of **nitrogen reduction per dollar spent**.



Ranking methodology 1:

BMP1
BMP2
BMP3

Ranking methodology 2:

BMP3
BMP2
BMP1

Ranking methodology 3:

BMP2 (\$12/lb N)
BMP3 (\$15/lb N)
BMP1 (\$24/lb N)

Results

1. BMP Selection ranking methodology based on Land use

Strategy 1: Rank the top BMPs based on the implementation acreages;

Table: Top choice BMPs based on the first ranking methodology

Urban Top-Ranked Counties	Agricultural Top-Ranked Counties
Strategy 1	Strategy 1
145: Nutrient Management Plan High-Risk Lawn	145: Nutrient Management Plan High-Risk Lawn
29: Off-Stream Watering Without Fencing	29: Off-Stream Watering Without Fencing
142: Nutrient Management N Timing	142: Nutrient Management N Timing
30: Precision Intensive Rotational/Prescribed Grazing	137: Nutrient Management N Rate
48: Cover Crop Traditional Rye Early Drilled	48: Cover Crop Traditional Rye Early Drilled
137: Nutrient Management N Rate	139: Nutrient Management N Placement
139: Nutrient Management N Placement	67: Barnyard Runoff Control

Results

1. BMP Selection ranking methodology based on Land use

Strategy 2: Rank the top BMPs based on the percentage of maximum allowable acreages

Table: Top choice BMPs based on the second-ranking methodology

Urban Top-Ranked Counties	Agricultural Top-Ranked Counties
Strategy 2	Strategy 2
67: Barnyard Runoff Control	67: Barnyard Runoff Control
10: Agricultural Stormwater Management	145: Nutrient Management Plan High-Risk Lawn
145: Nutrient Management Plan High-Risk Lawn	137: Nutrient Management N Rate
3: Soil Conservation and Water Quality Plans	142: Nutrient Management N Timing
29: Off-Stream Watering Without Fencing	10: Agricultural Stormwater Management
139: Nutrient Management N Placement	139: Nutrient Management N Placement
137: Nutrient Management N Rate	29: Off-Stream Watering Without Fencing

Results

1. BMP Selection ranking methodology based on Land use

Strategy 3: Rank the top BMPs based on the amount of nitrogen reduction per dollar spent.

Table: Top choice BMPs based on the third strategy

Urban Top-Ranked Counties	Agricultural Top-Ranked Counties
Strategy 3	Strategy 3
145: Nutrient Management Plan High-Risk Lawn	145: Nutrient Management Plan High-Risk Lawn
29: Off-Stream Watering Without Fencing	29: Off-Stream Watering Without Fencing
137: Nutrient Management N Rate	137: Nutrient Management N Rate
46: Forest Harvesting Practices	142: Nutrient Management N Timing
142: Nutrient Management N Timing	48: Cover Crop Traditional Rye Early Drilled
48: Cover Crop Traditional Rye Early Drilled	139: Nutrient Management N Placement
139: Nutrient Management N Placement	49: Cover Crop Traditional Rye Early Other

Results

All three-ranking methodologies:

Urban Top-Ranked Counties			Agricultural Top-Ranked Counties		
Strategy 1	Strategy 2	Strategy 3	Strategy 1	Strategy 2	Strategy 3
Nutrient Management Plan High-Risk Lawn	Barnyard Runoff Control	Nutrient Management Plan High-Risk Lawn	Nutrient Management Plan High-Risk Lawn	Barnyard Runoff Control	Nutrient Management Plan High-Risk Lawn
Off Stream Watering Without Fencing	Agricultural Stormwater Management	Off Stream Watering Without Fencing	Off Stream Watering Without Fencing	Nutrient Management Plan High-Risk Lawn	Off Stream Watering Without Fencing
Nutrient Management N Timing	Nutrient Management Plan High-Risk Lawn	Nutrient Management N Rate	Nutrient Management N Timing	Nutrient Management N Rate	Nutrient Management N Rate
Precision Intensive Rotational/Prescribed Grazing	Soil Conservation and Water Quality Plans	Forest Harvesting Practices	Nutrient Management N Rate	Nutrient Management N Timing	Nutrient Management N Timing
Cover Crop Traditional Rye Early Drilled	Off Stream Watering Without Fencing	Nutrient Management N Timing	Cover Crop Traditional Rye Early Drilled	Agricultural Stormwater Management	Cover Crop Traditional Rye Early Drilled
Nutrient Management N Rate	Nutrient Management N Placement	Cover Crop Traditional Rye Early Drilled	Nutrient Management N Placement	Nutrient Management N Placement	Nutrient Management N Placement
Nutrient Management N Placement	Nutrient Management N Rate	Nutrient Management N Placement	Barnyard Runoff Control	Off Stream Watering Without Fencing	Cover Crop Traditional Rye Early Other

Results

2. Identify the similarities and differences between top-rank BMPs selected in agricultural and urban settings,

Similarities:

- **Top BMP choice:** Nutrient management lawn or farm
- **The pasturelands:** Off-stream watering facilities

Differences:

- Also, more diversity in BMP types was in agricultural settings compared to urban ones.
- **knowledge discovery:** consider the above-mentioned BMPs (i.e., # Nutrient Management Plan High-Risk Lawn, Off-Stream Watering Without Fencing, and Nutrient Management N Rate) in the initial population.

Results

3. Recommend an innovative approach to reduce the optimization time

- Obtaining **the total ranking of each BMP** by adding the associated ranking to individual BMPs.

Overall Top-ranked BMP
Nutrient Management Plan High-Risk Lawn
Off-Stream Watering Without Fencing
Nutrient Management N Rate
Nutrient Management N Timing
Barnyard Runoff Control
Cover Crop Traditional Rye Early Drilled
Nutrient Management N Placement

3. Recommend an innovative approach to reduce the optimization time

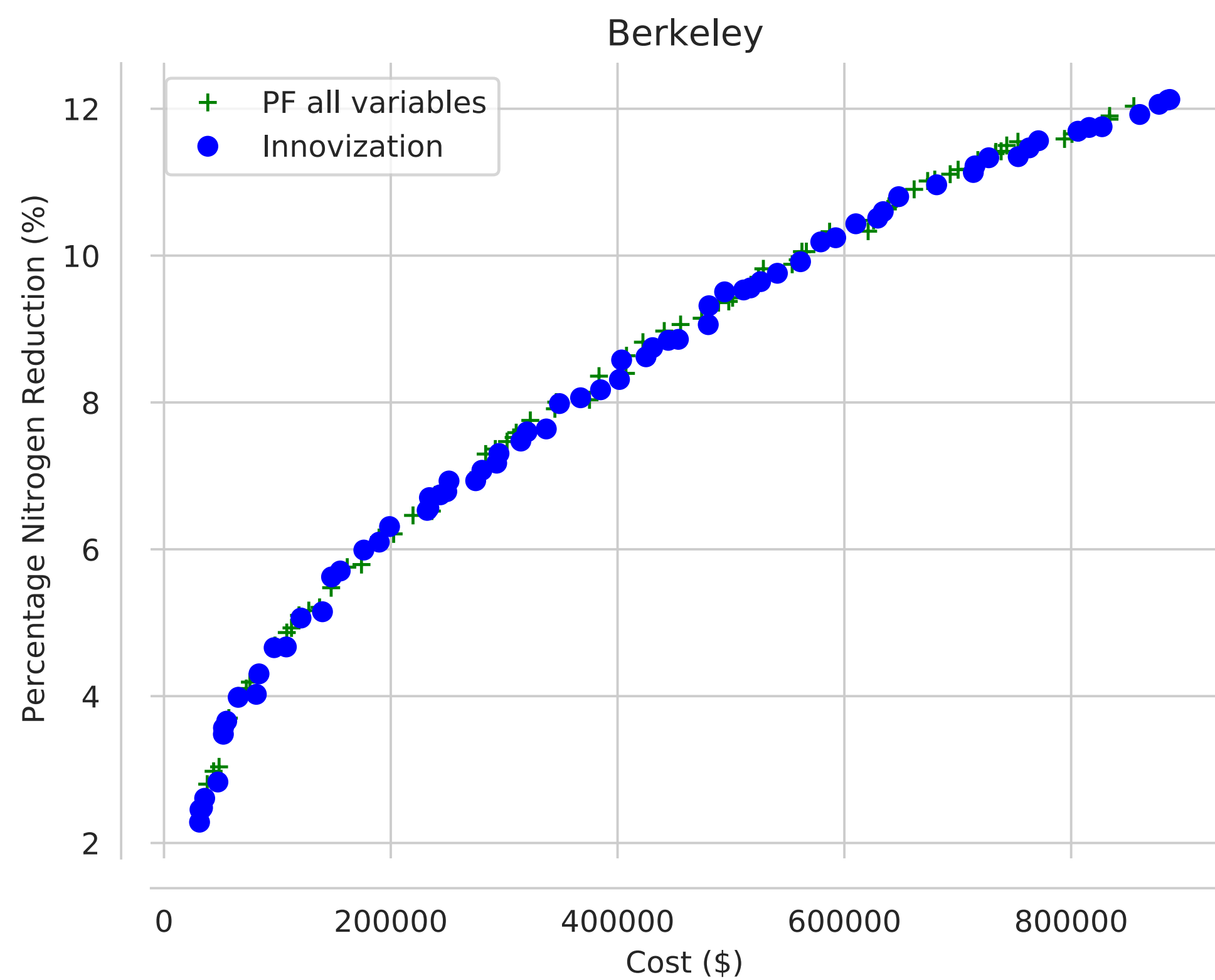
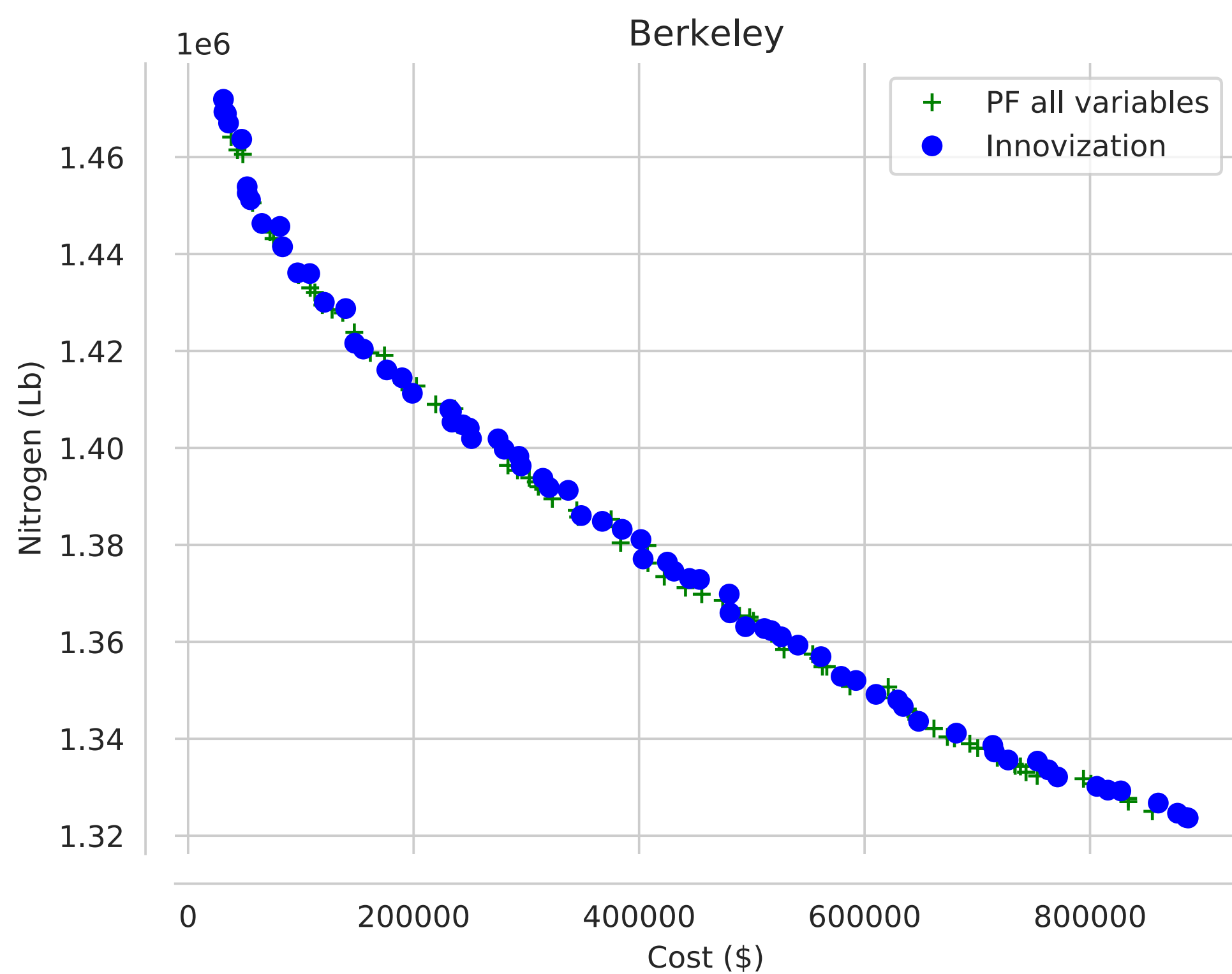
- Recommend the selection of **the top seven BMPs from the overall column** for optimization.
- Can be used in developing the initial population in other counties within the state of West Virginia?.
- **Hypothesis:** the careful selection of BMPs can lead to a reduction of search space and improve the optimization process.

Variable reduction.

Table 1

	Original Variables	Variables (innovization)
Hardy	18,607	725
Berkeley	14,090	510
Jefferson	12,303	456
Mineral	20,260	765

Results for Berkeley County



Conclusions and Future Work

- We have developed **multi-objective** methods that accept users' **preferences** and find several **solutions** in a **single run**.
- The implemented different ways to introduce the preferences and run our approaches: API and Web.
- Such a tool will help us reduce the time to evaluate and analyze our optimization algorithms.
- Innovization can help us to perform more efficient search.
- The results are promising, and we are planning to incorporate these results in the design of our future approaches.
- The decision-making process (future work).

Thank you!