Modeling Workgroup Meeting Quarterly Review

Optimization update

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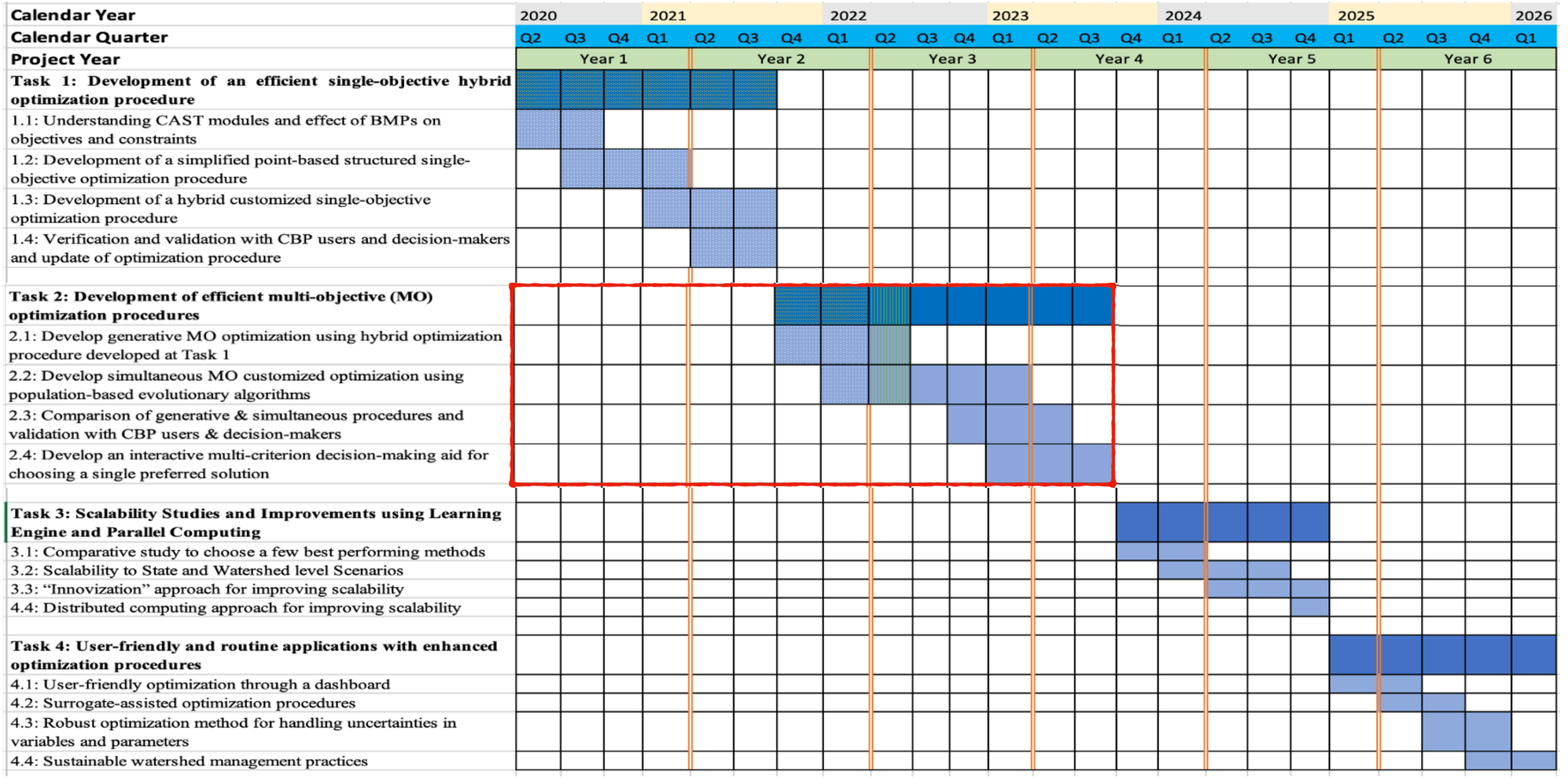
MICHIGAN STATE UNIVERSITY, JAN 2023

Overview

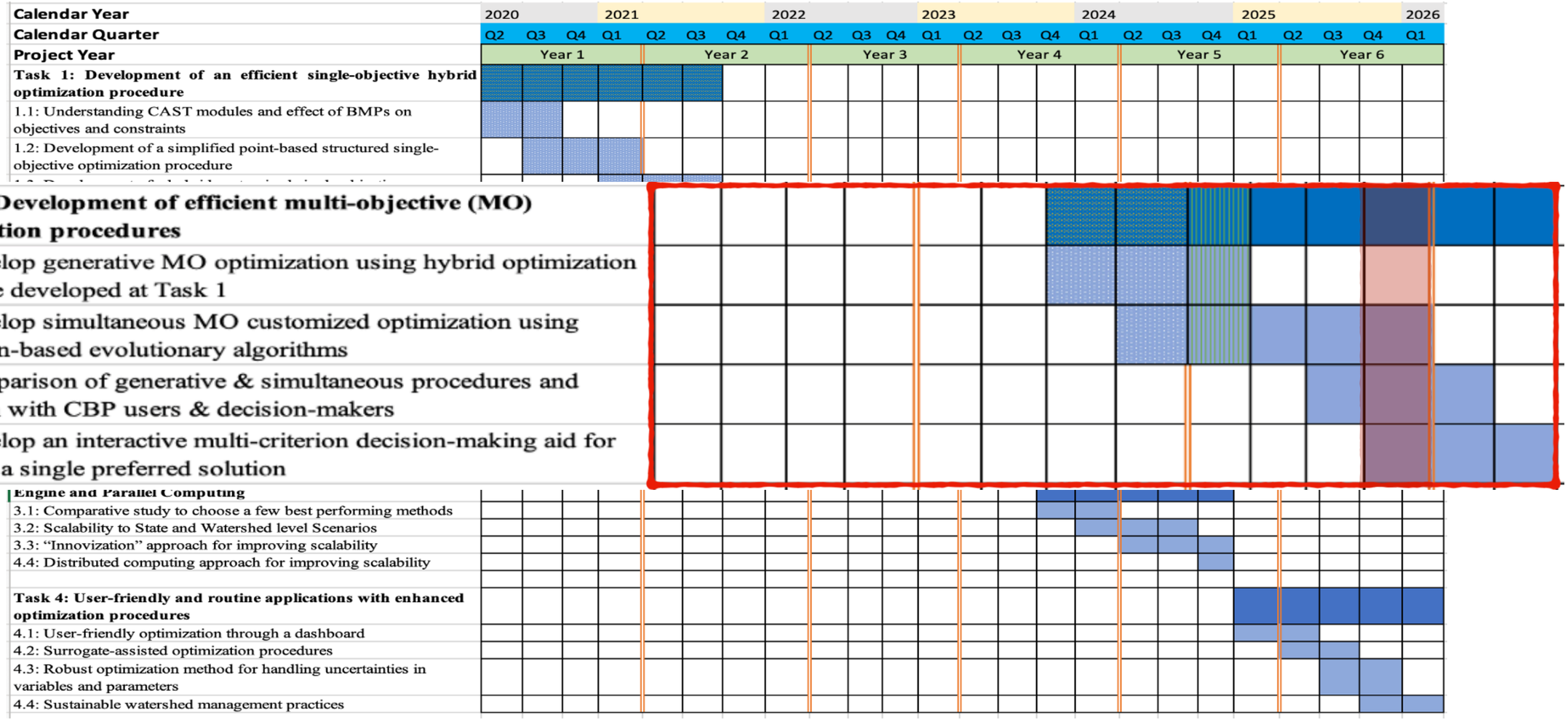
- Objective 2: Development of Efficient Multi-objective Optimization Procedures
  - Oct 1, 2021 to September 30, 2023 (24 months)

- 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

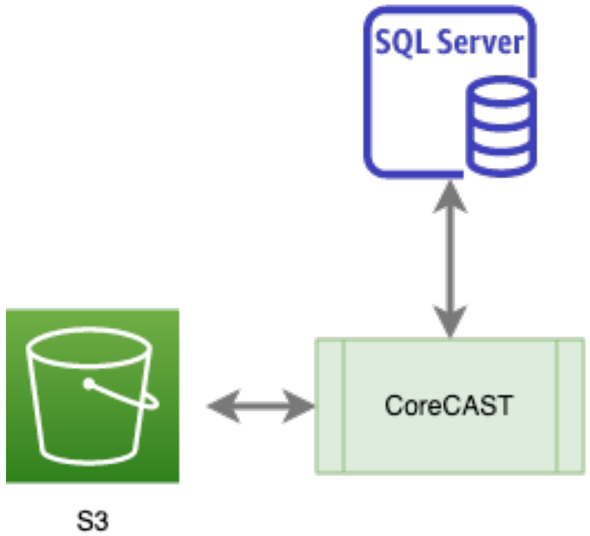
Current status of the project

- 

Current status of the project



Project Progress



Project Progress

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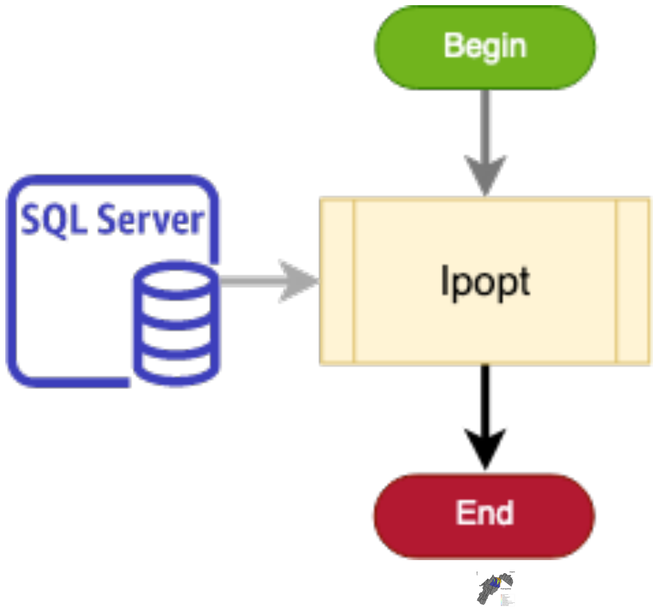

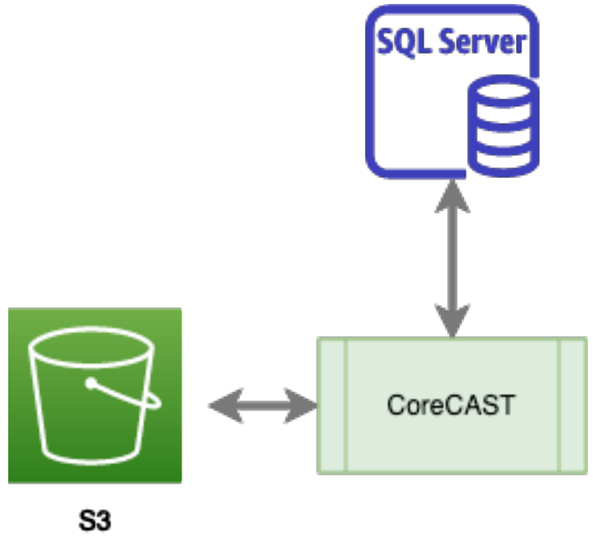

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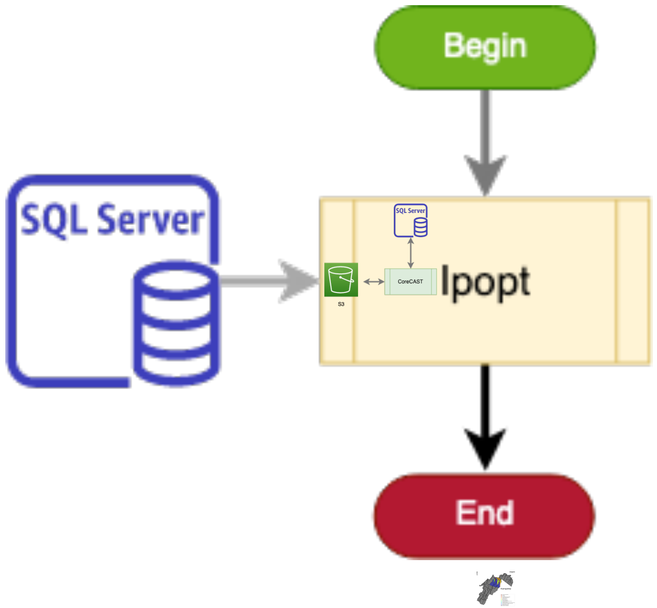

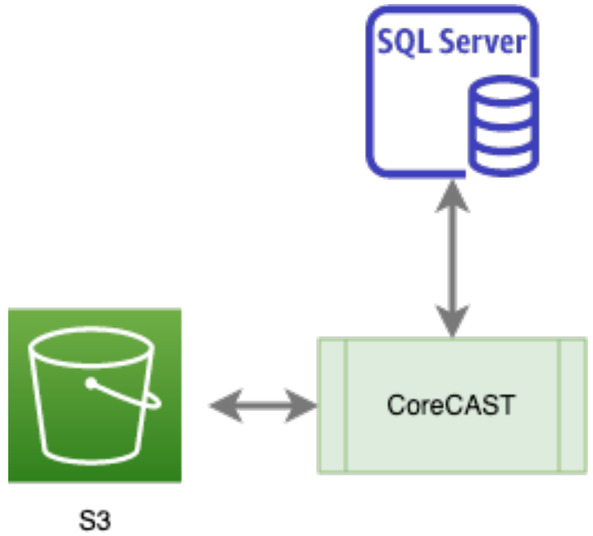

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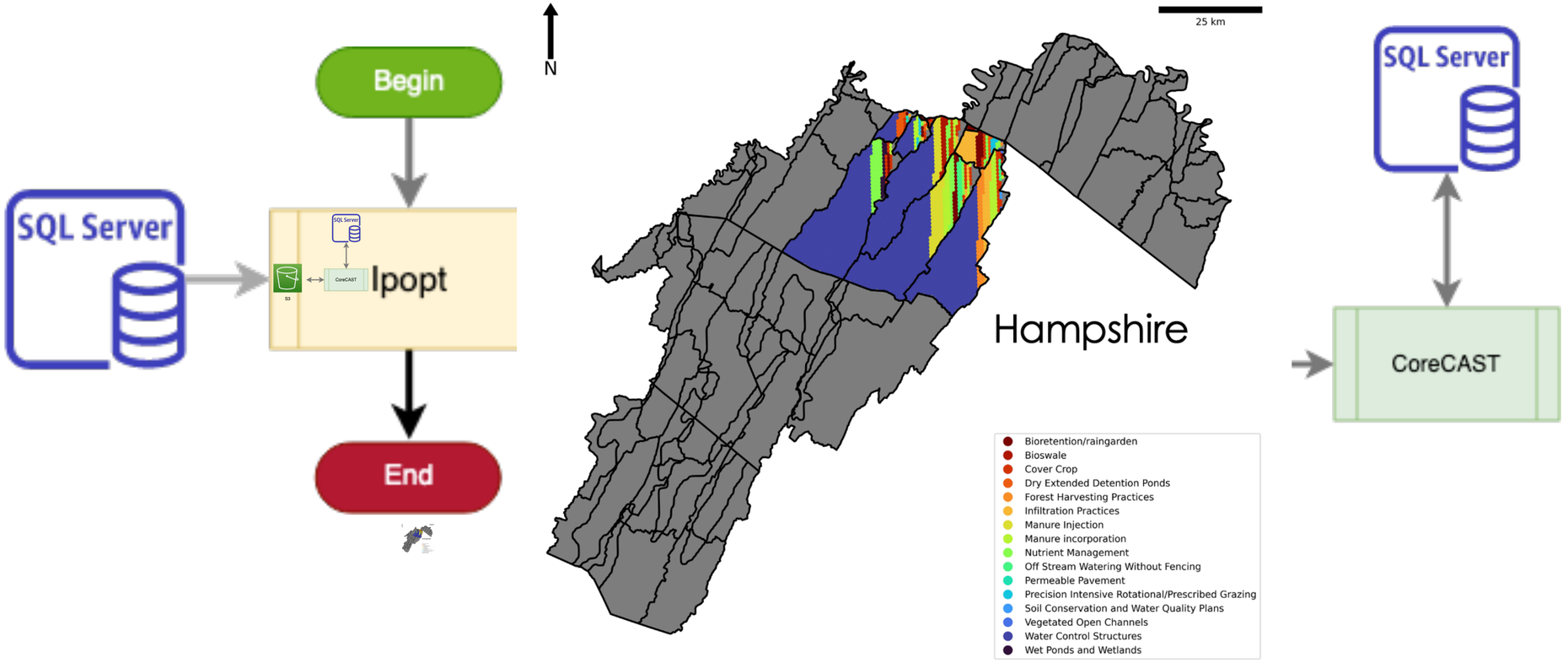

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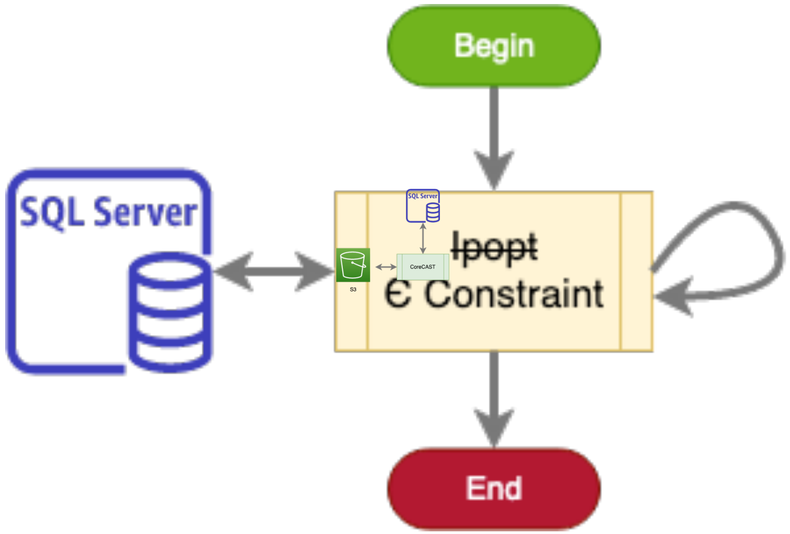

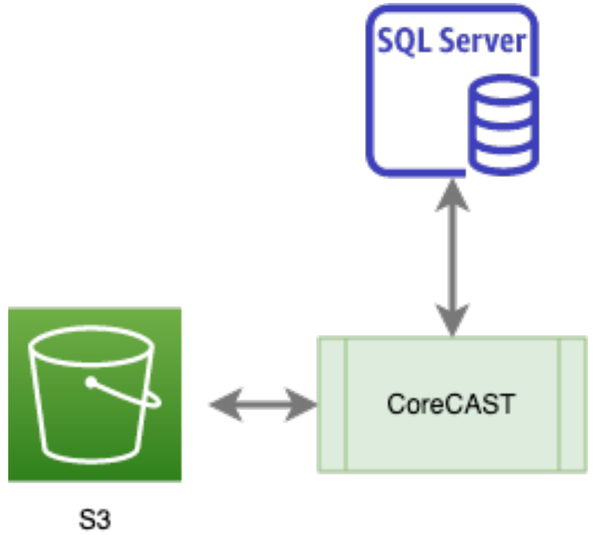

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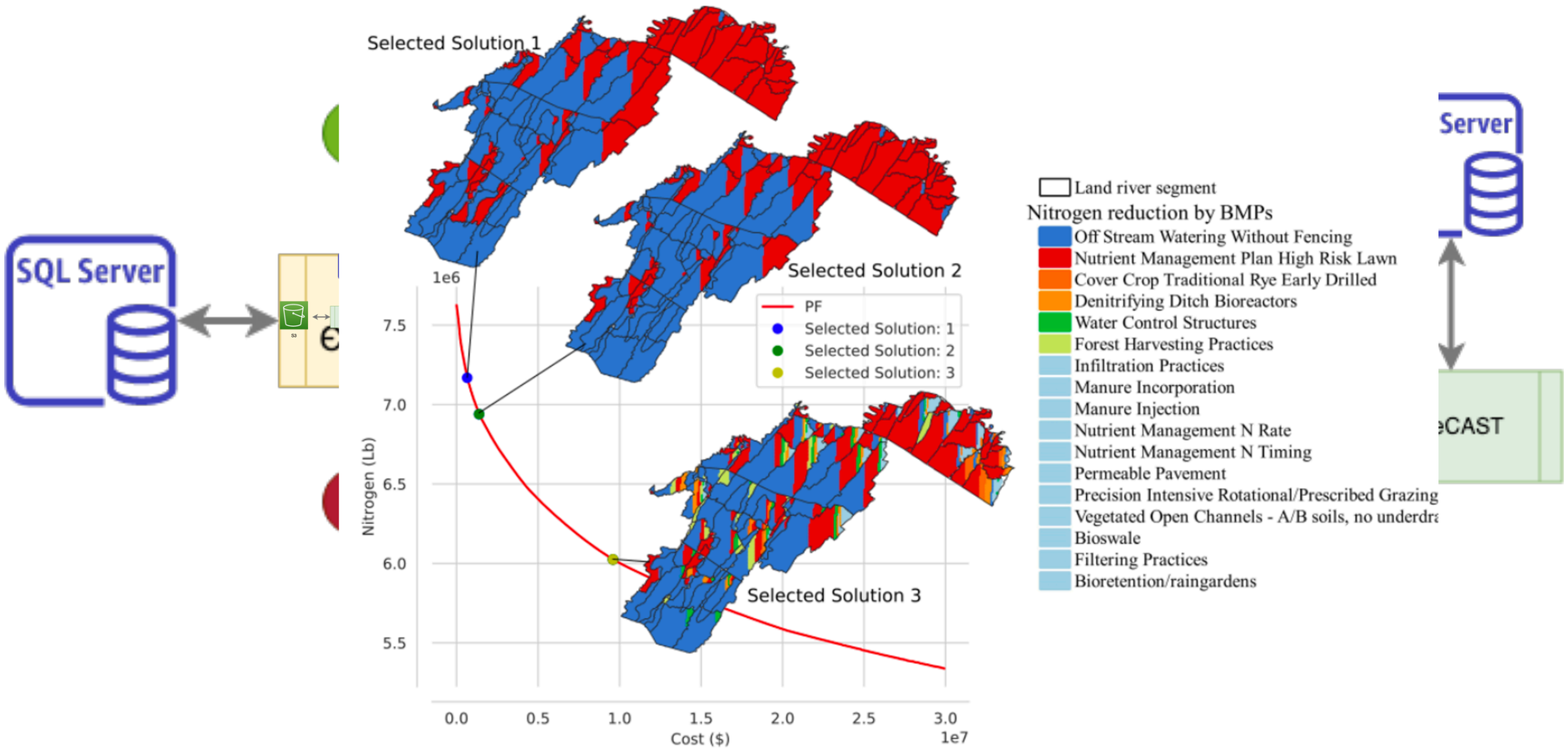

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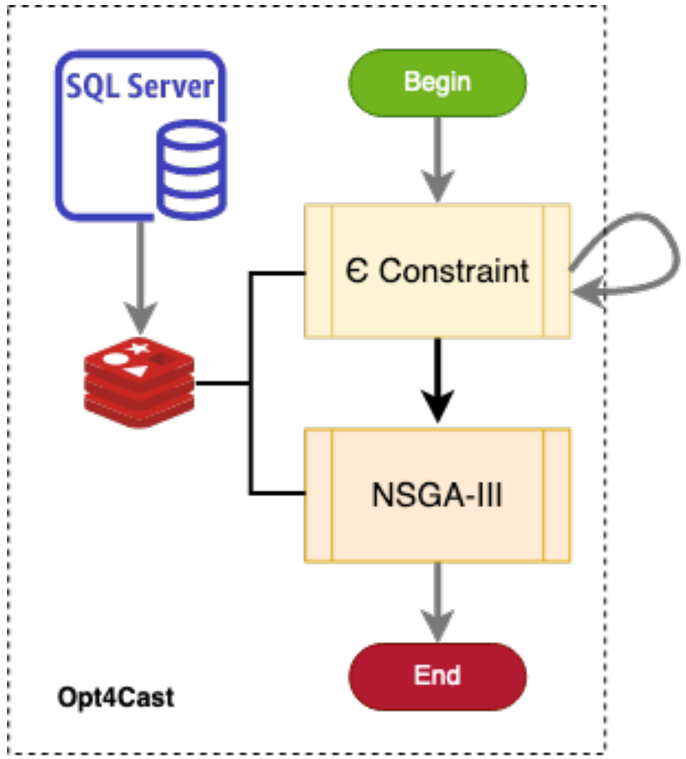

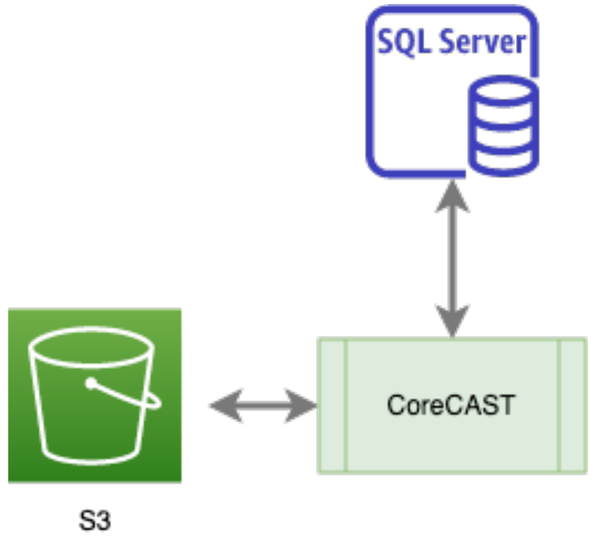

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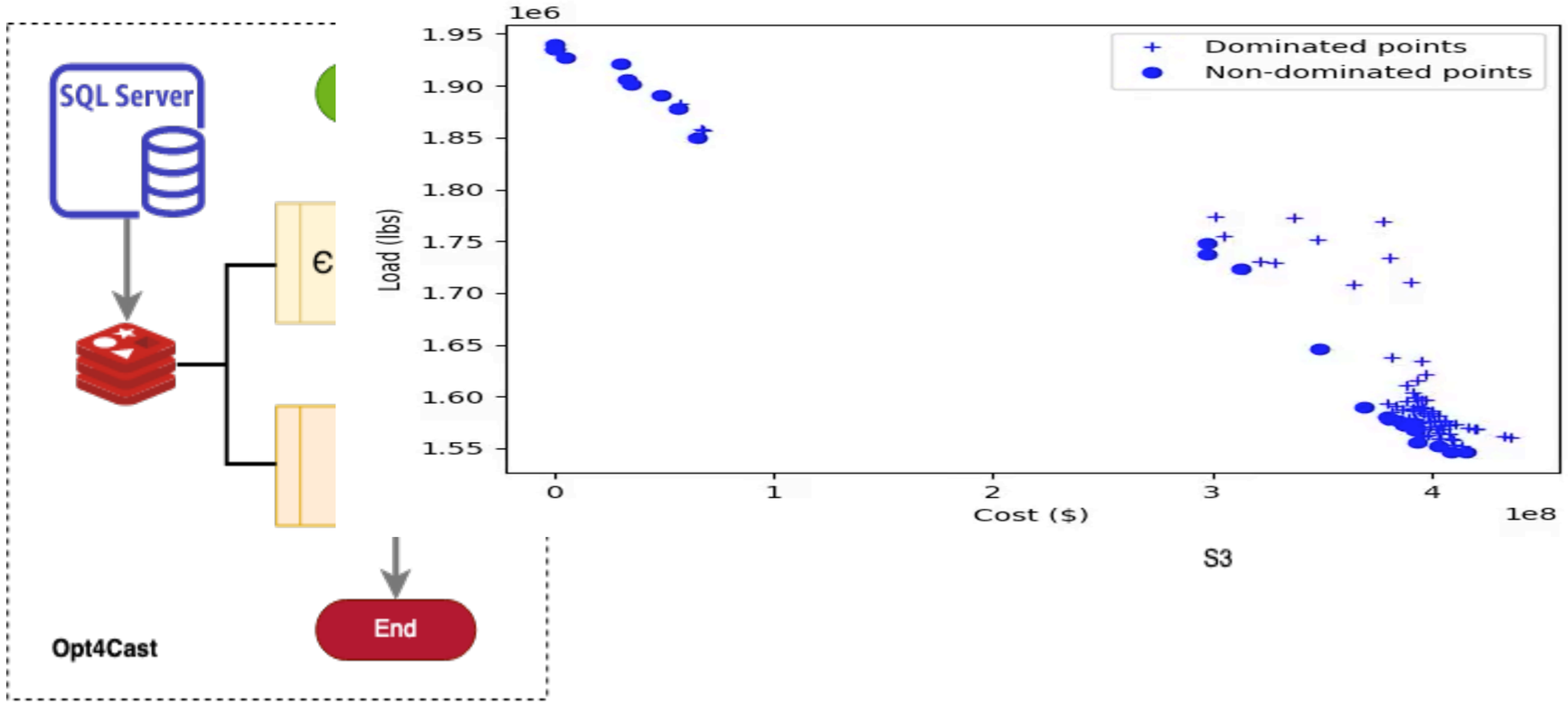

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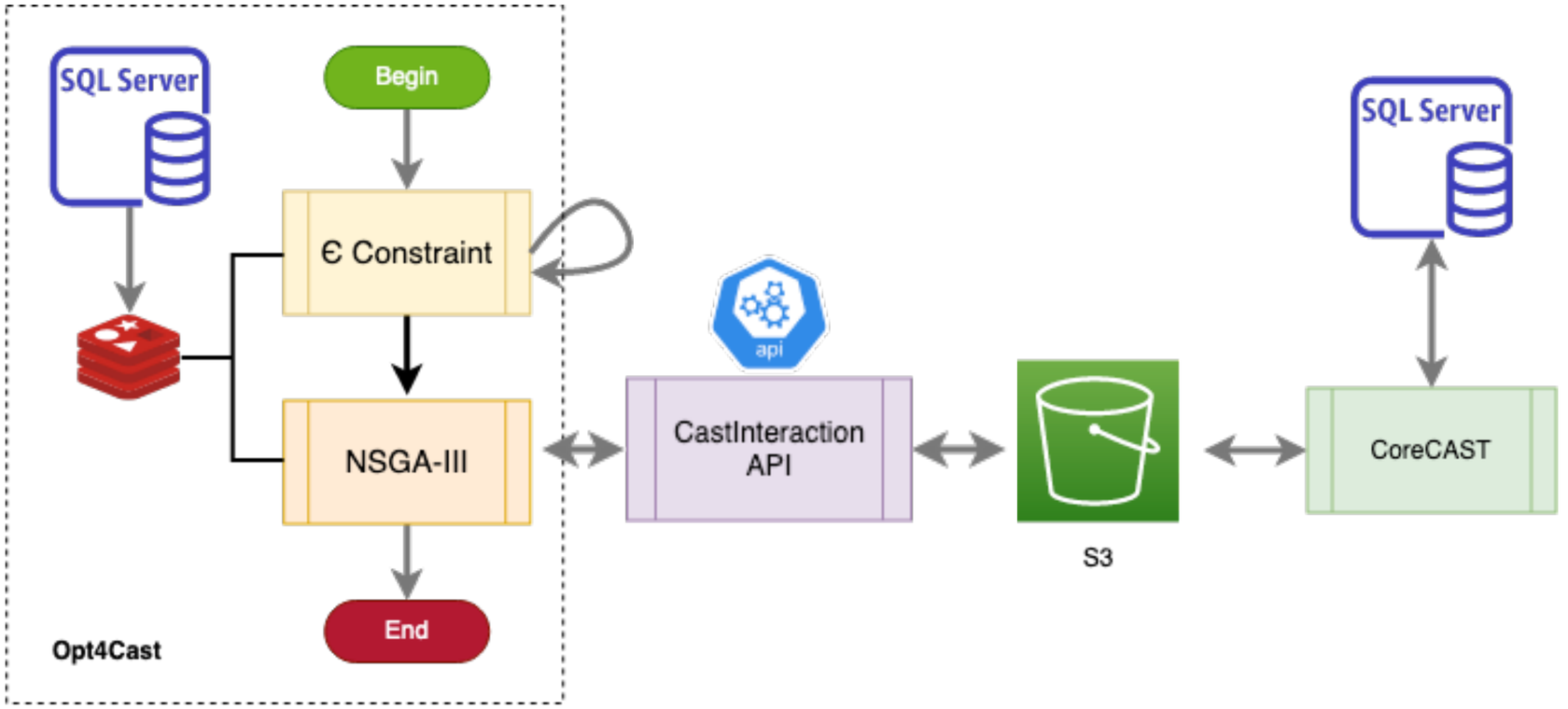

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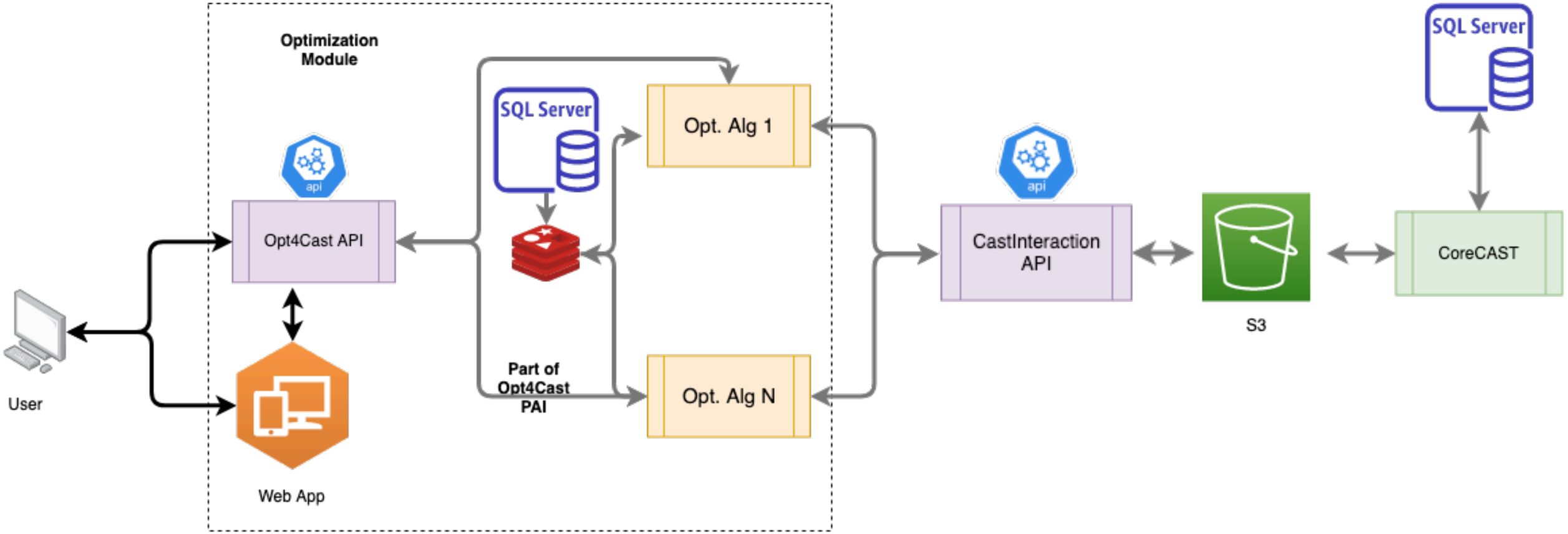

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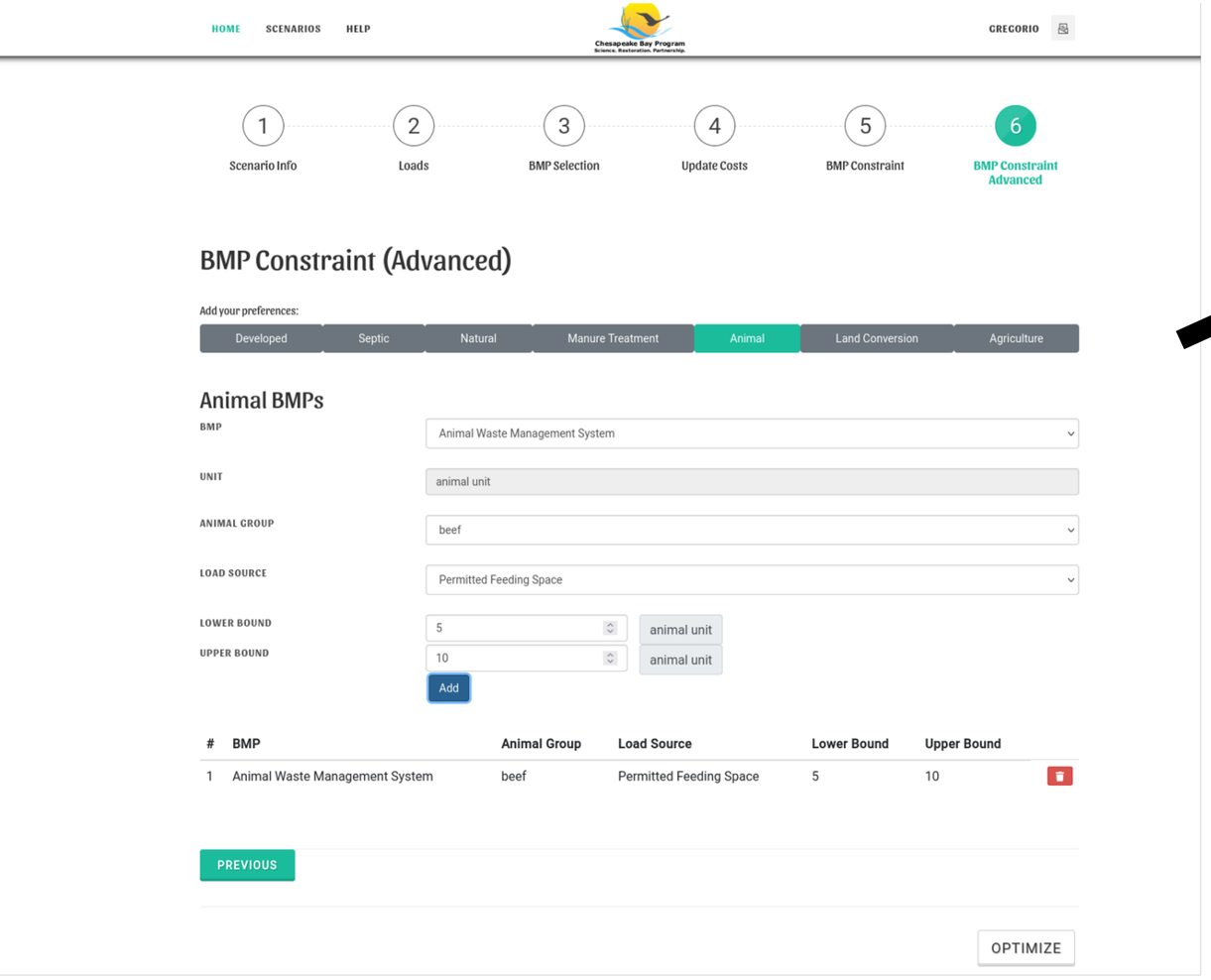
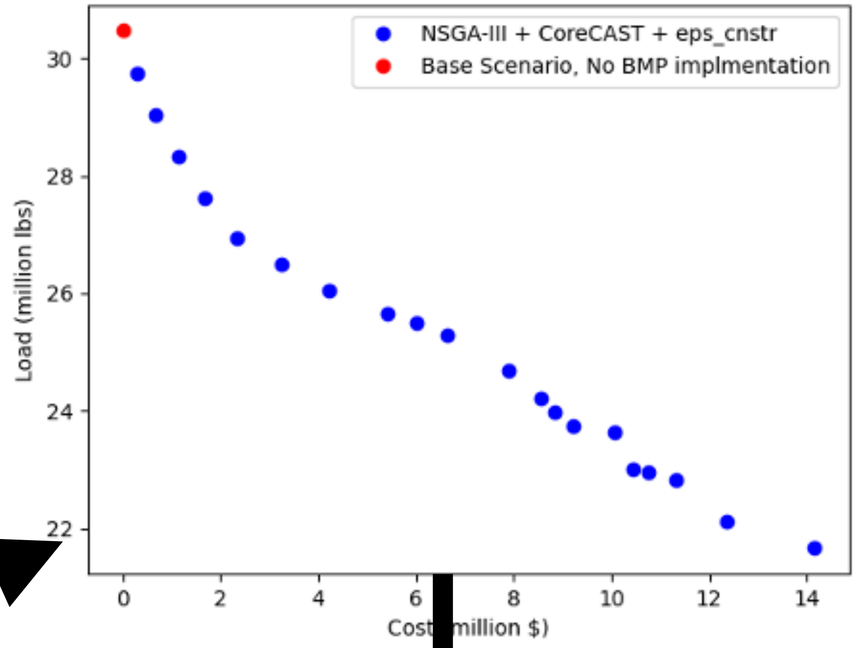
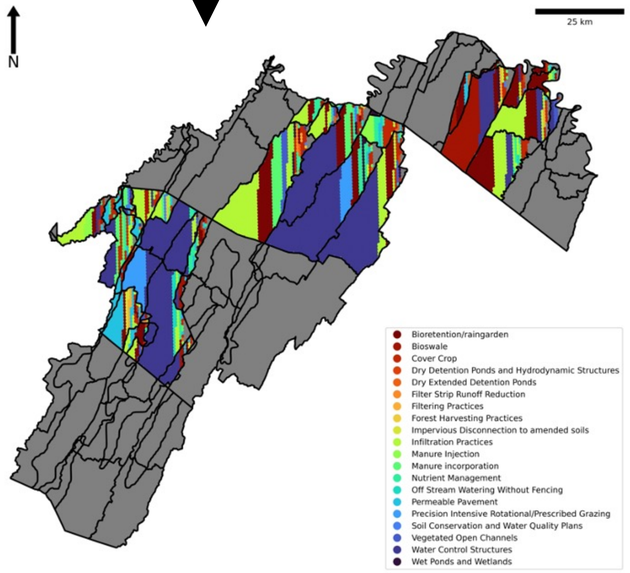
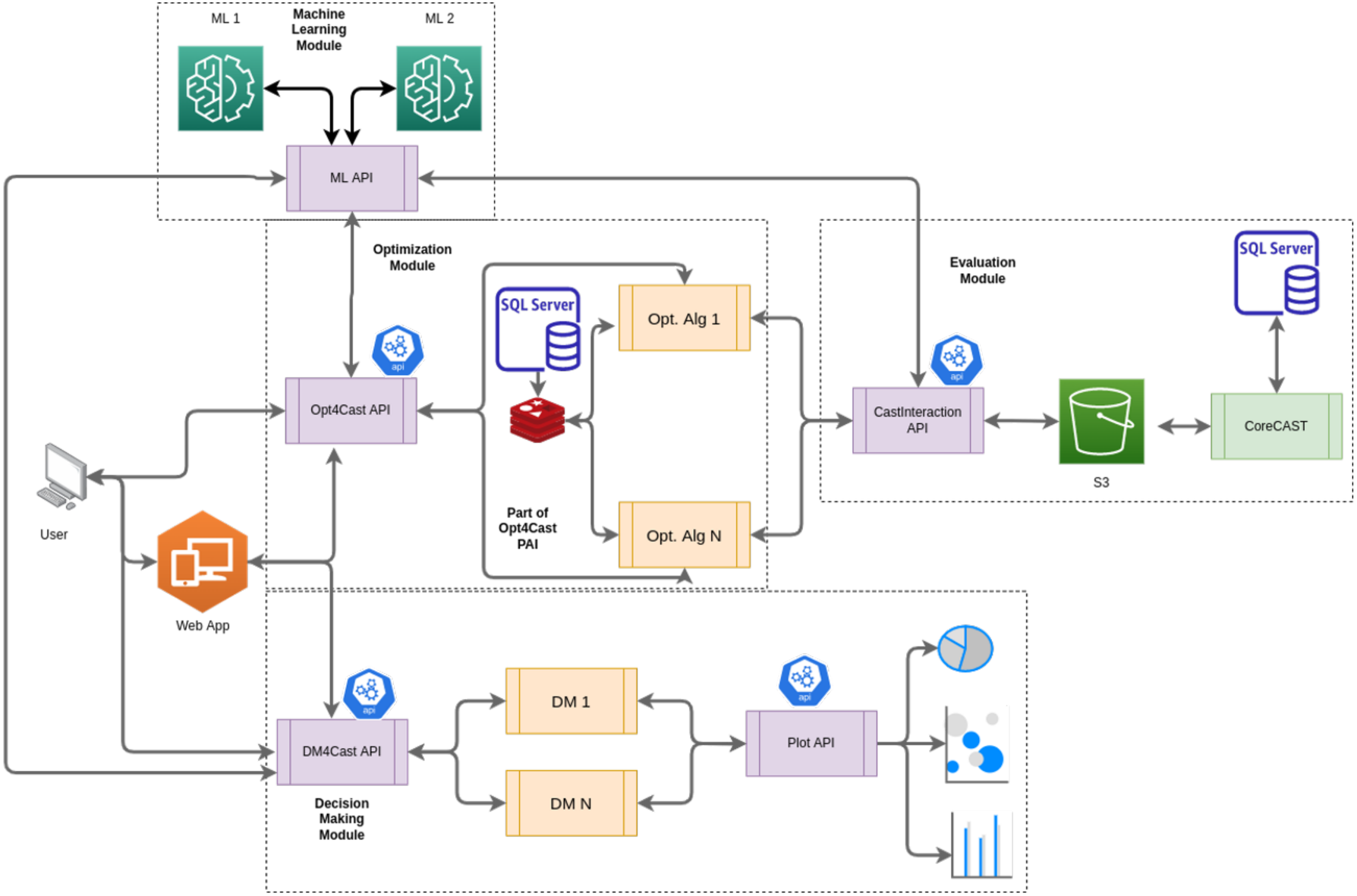


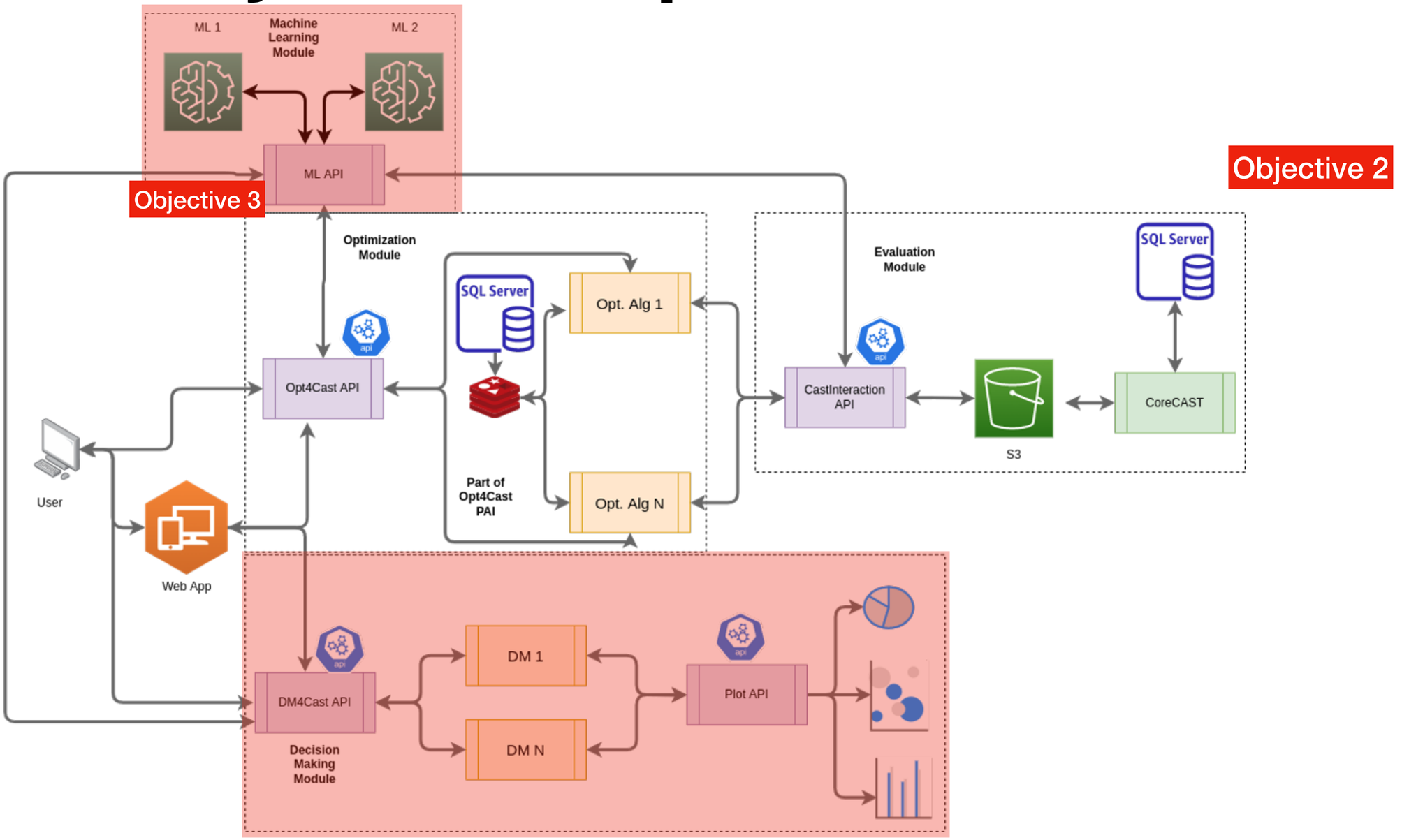




Projected Project Development

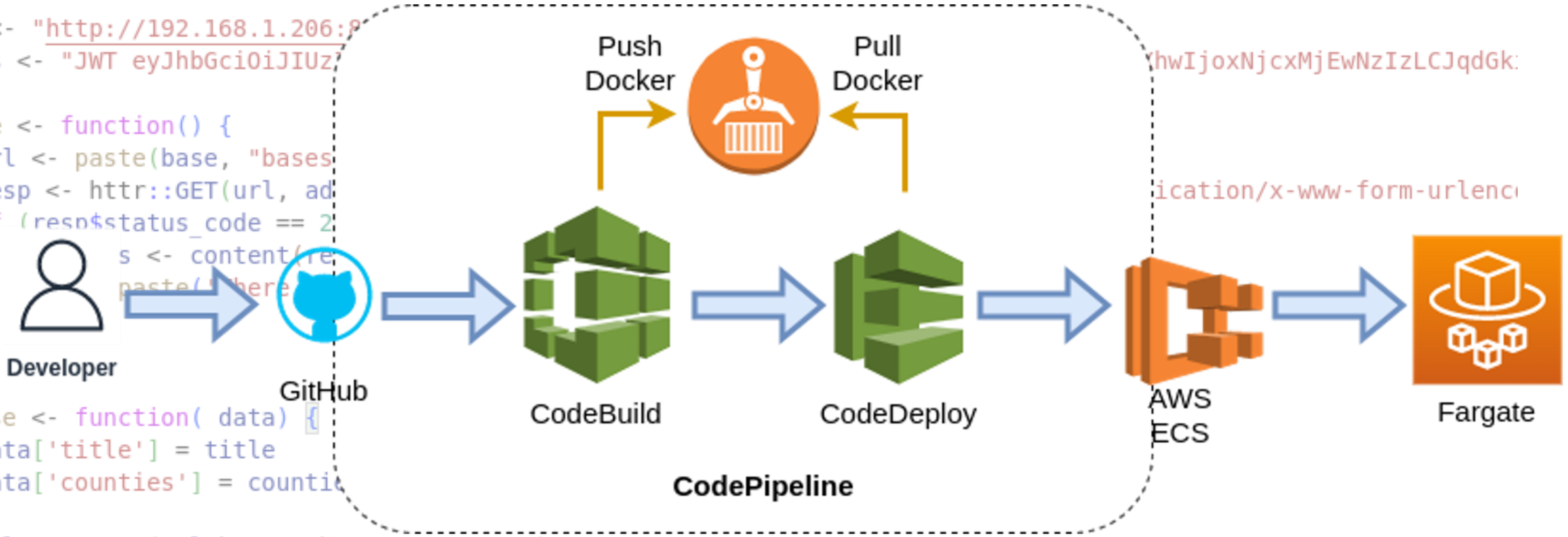


Projected Project Development



Currently running under the CBPO infrastructure*

Continuous Integration / Continues Development in AWS



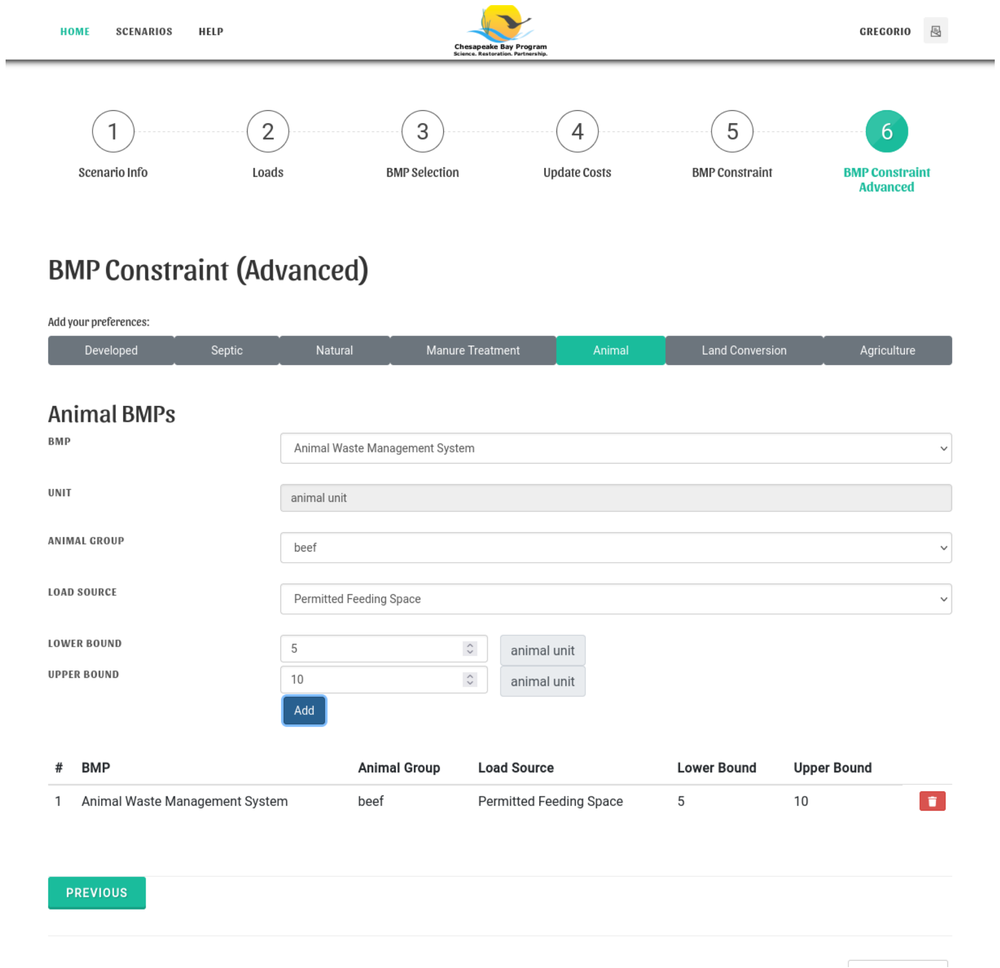
Tested with Python, R, C++, Julia, and Go

***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.



*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:

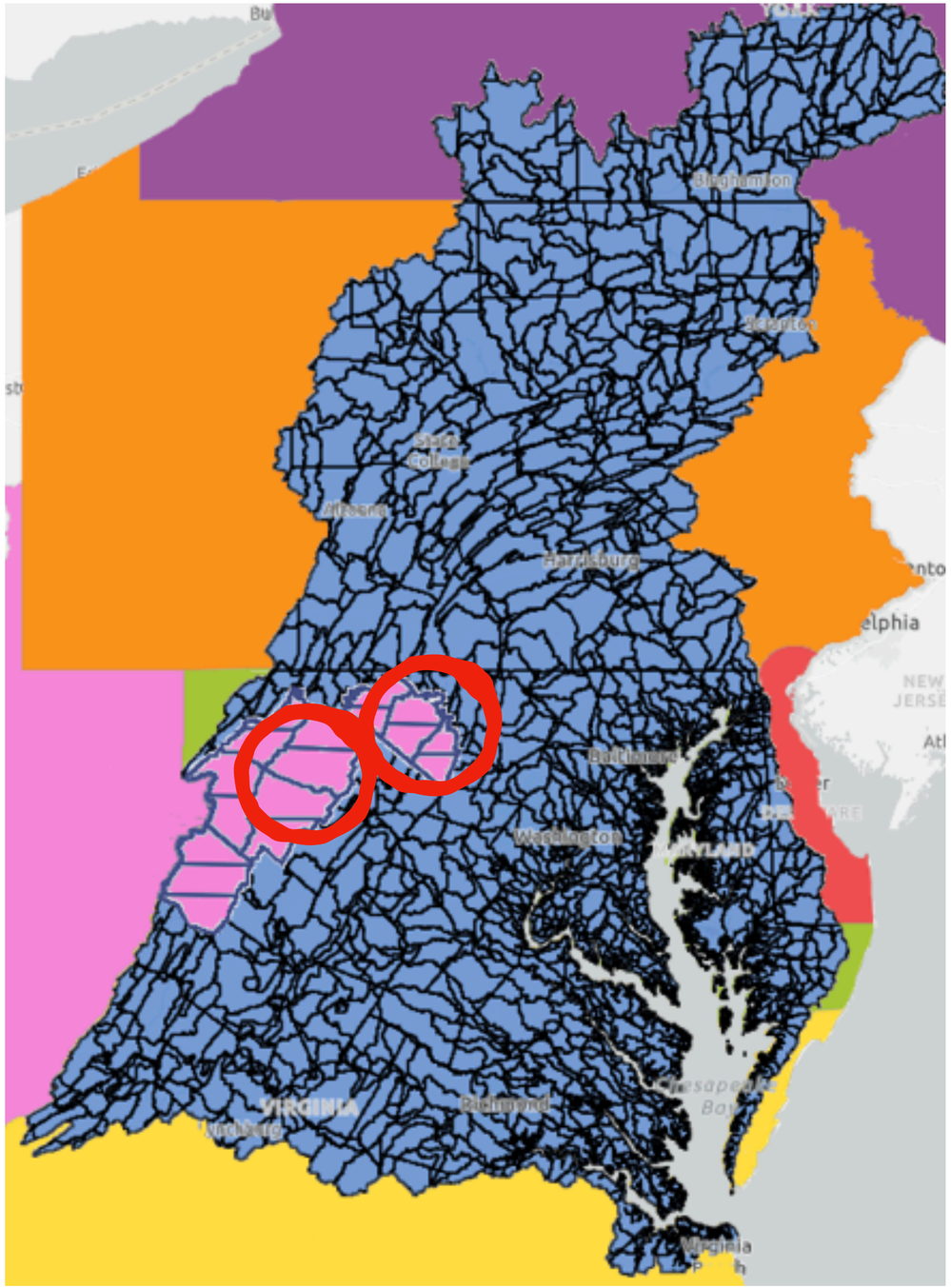
A. Examine different ranking methodologies to **identify the top BMPs**,
B. Identify the **similarities and differences** between top-ranked BMPs,
C. Provide recommendations to **improve the optimization process.**

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.

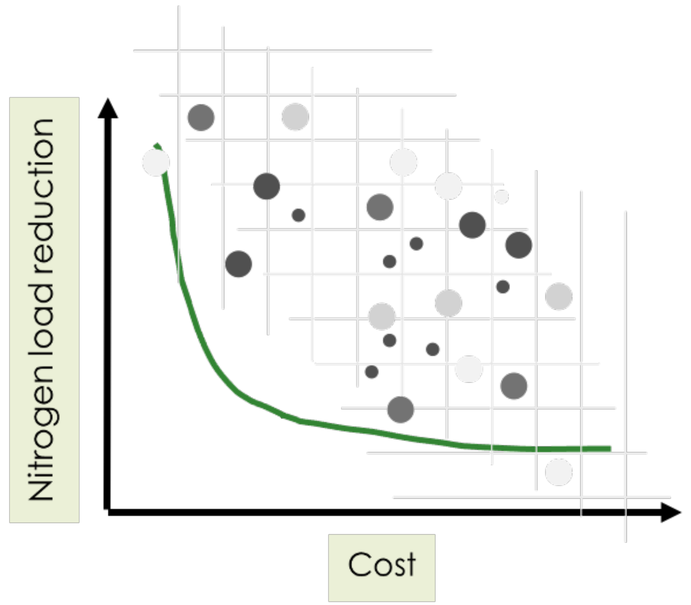
- (Berkeley and Mineral): Urban dominated
- (Jefferson and Hardy): Agricultural dominated



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**.



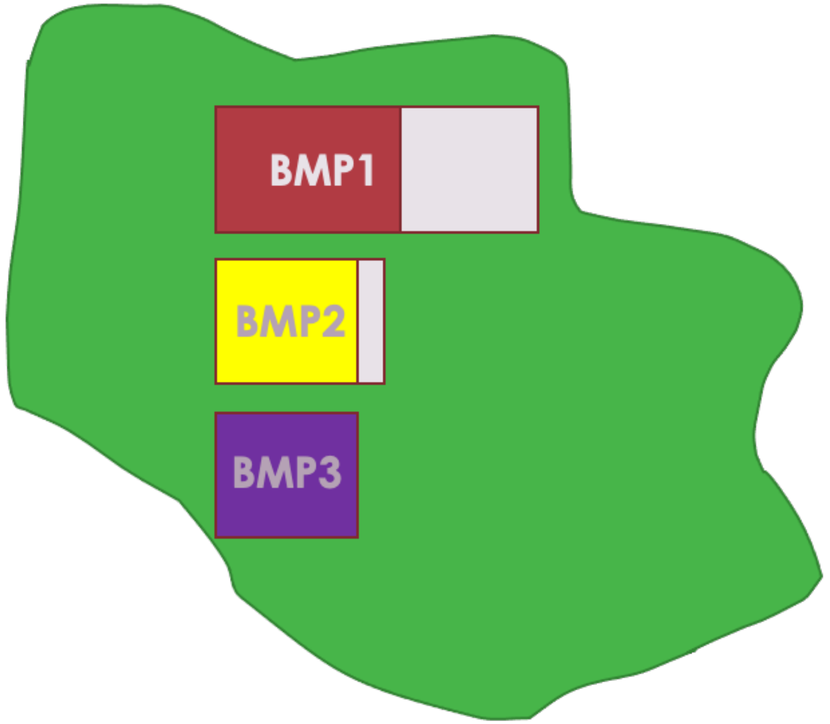
Methodology

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

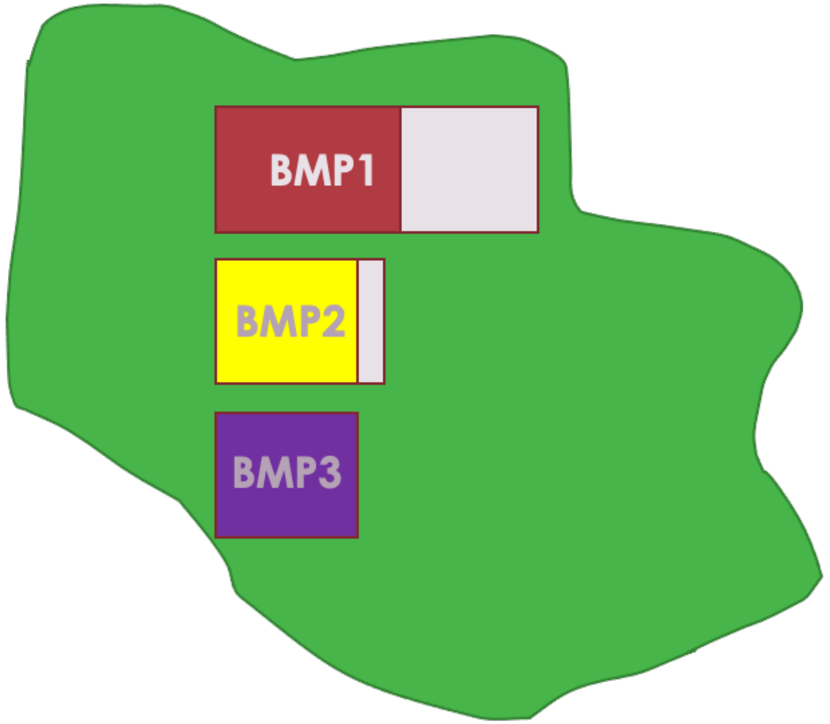
Methodology

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:

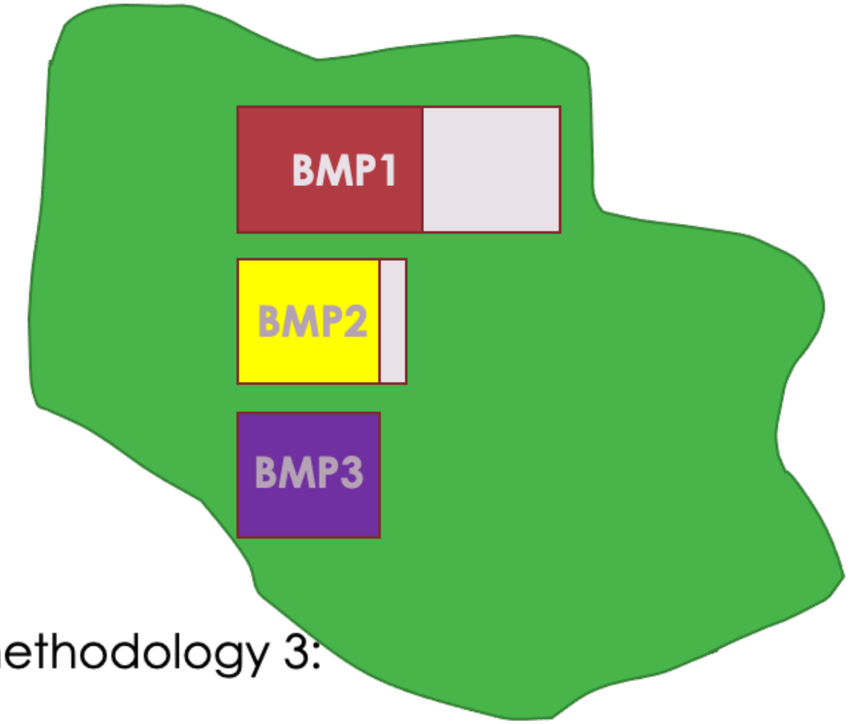
BMP3
BMP2
BMP1

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:

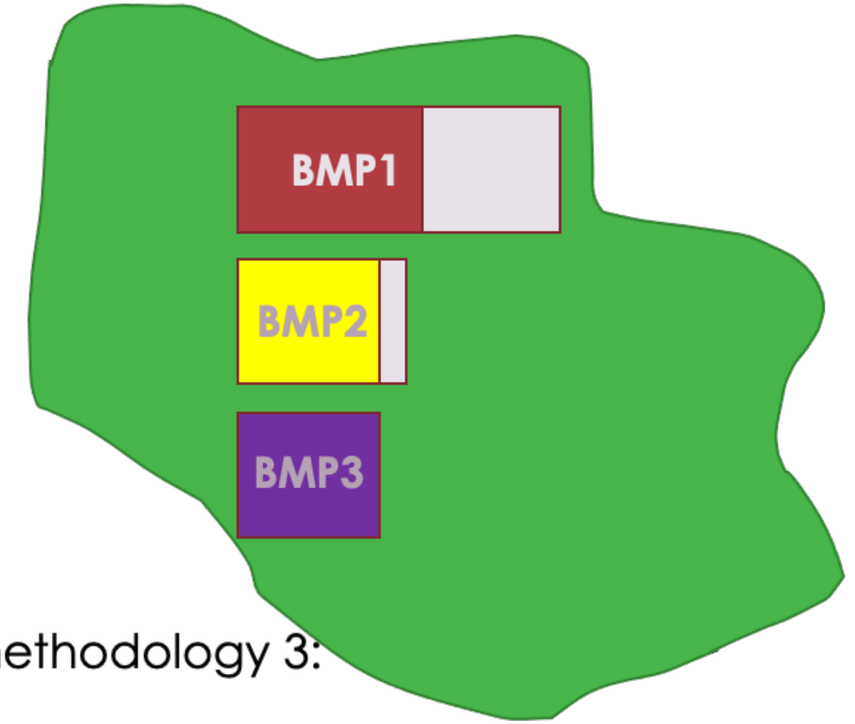
BMP2 ($12/lb N)
BMP3 ($15/lb N)
BMP1($24/lb N)

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

Agricultural Top-Ranked Counties		
Strategy 1	Strategy 2	Strategy 3
Nutrient Management Plan High-Risk Lawn	Barnyard Runoff Control	Nutrient Management Plan High-Risk Lawn
Off Stream Watering Without Fencing	Nutrient Management Plan High-Risk Lawn	Off Stream Watering Without Fencing
Nutrient Management N Timing	Nutrient Management N Rate	Nutrient Management N Rate
Nutrient Management N Rate	Nutrient Management N Timing	Nutrient Management N Timing
Cover Crop Traditional Rye Early Drilled	Agricultural Stormwater Management	Cover Crop Traditional Rye Early Drilled
Nutrient Management N Placement	Nutrient Management N Placement	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 induvial 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

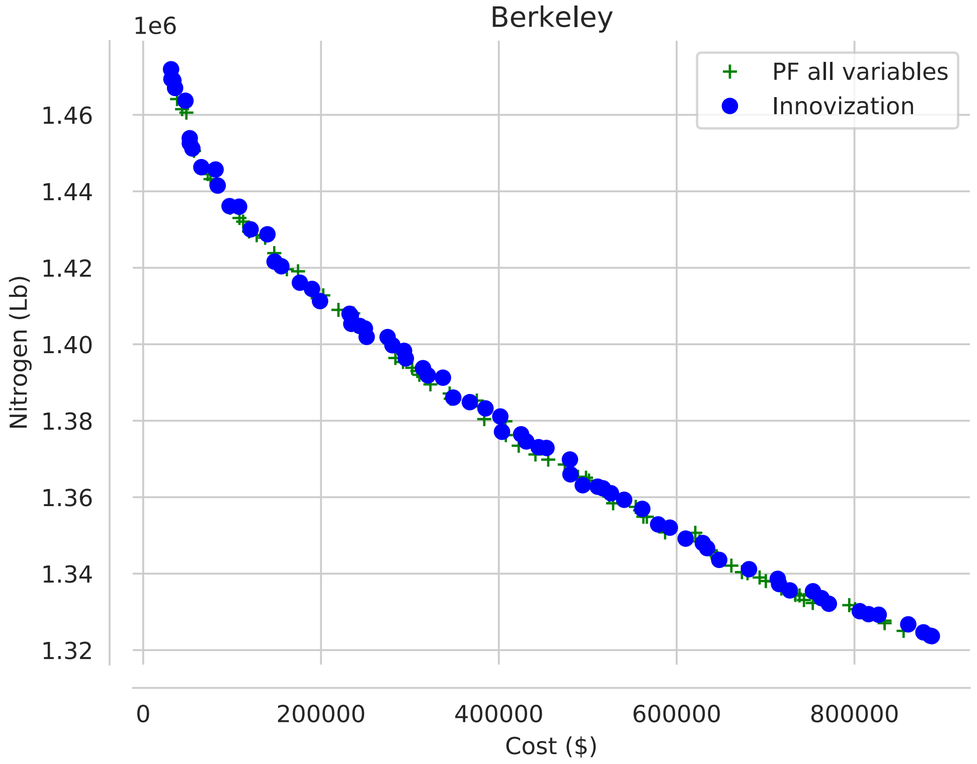
- Recommend the selection of **the top seven BMPs from the overall column** for optimization.
- Can be used in developing the initial population in other counties within the state of West Virginia?.
- **Hypothesis: t**he careful selection of BMPs can lead to a reduction of search space and improve the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

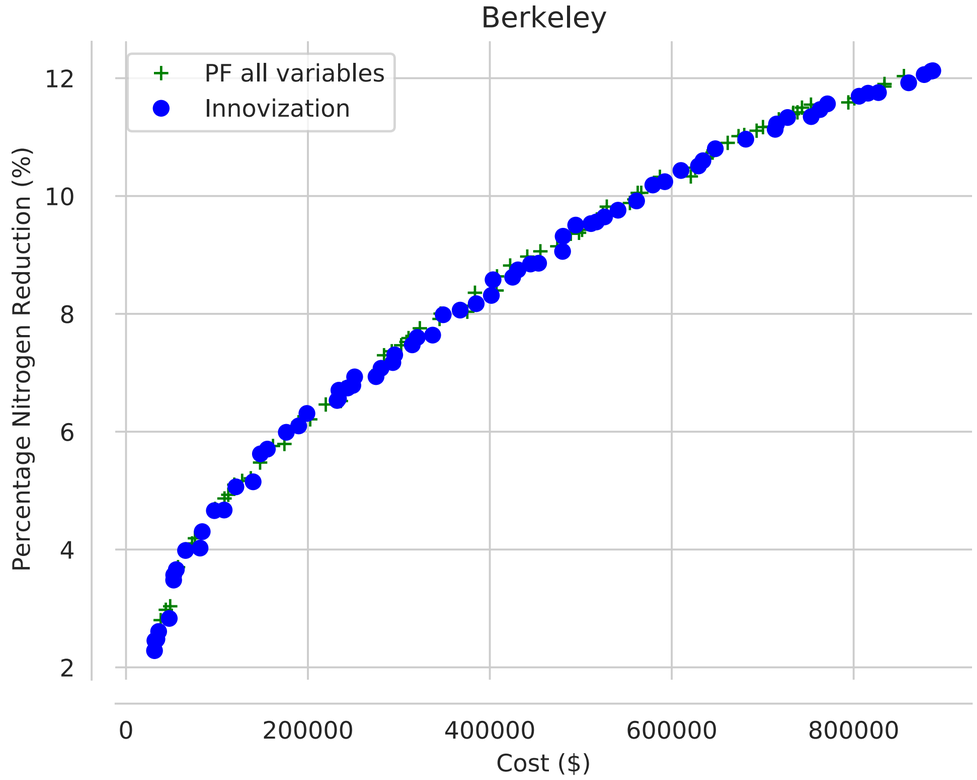
Variable reduction.

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!