Quarterly Members
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Optimization Update

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Agenda

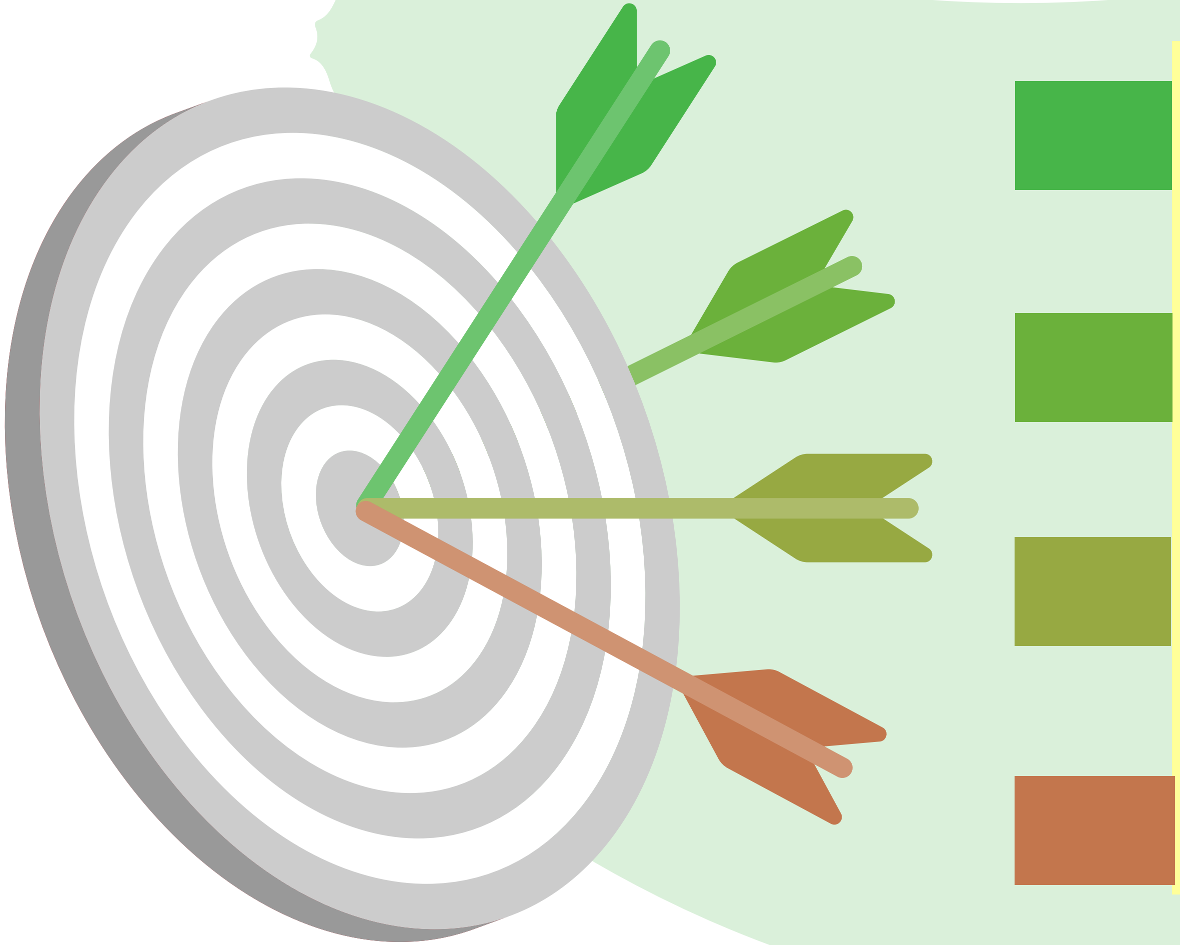
1 Objective of the project

2 Timeline

3 Performed experiments

4 Conclusions & Next steps

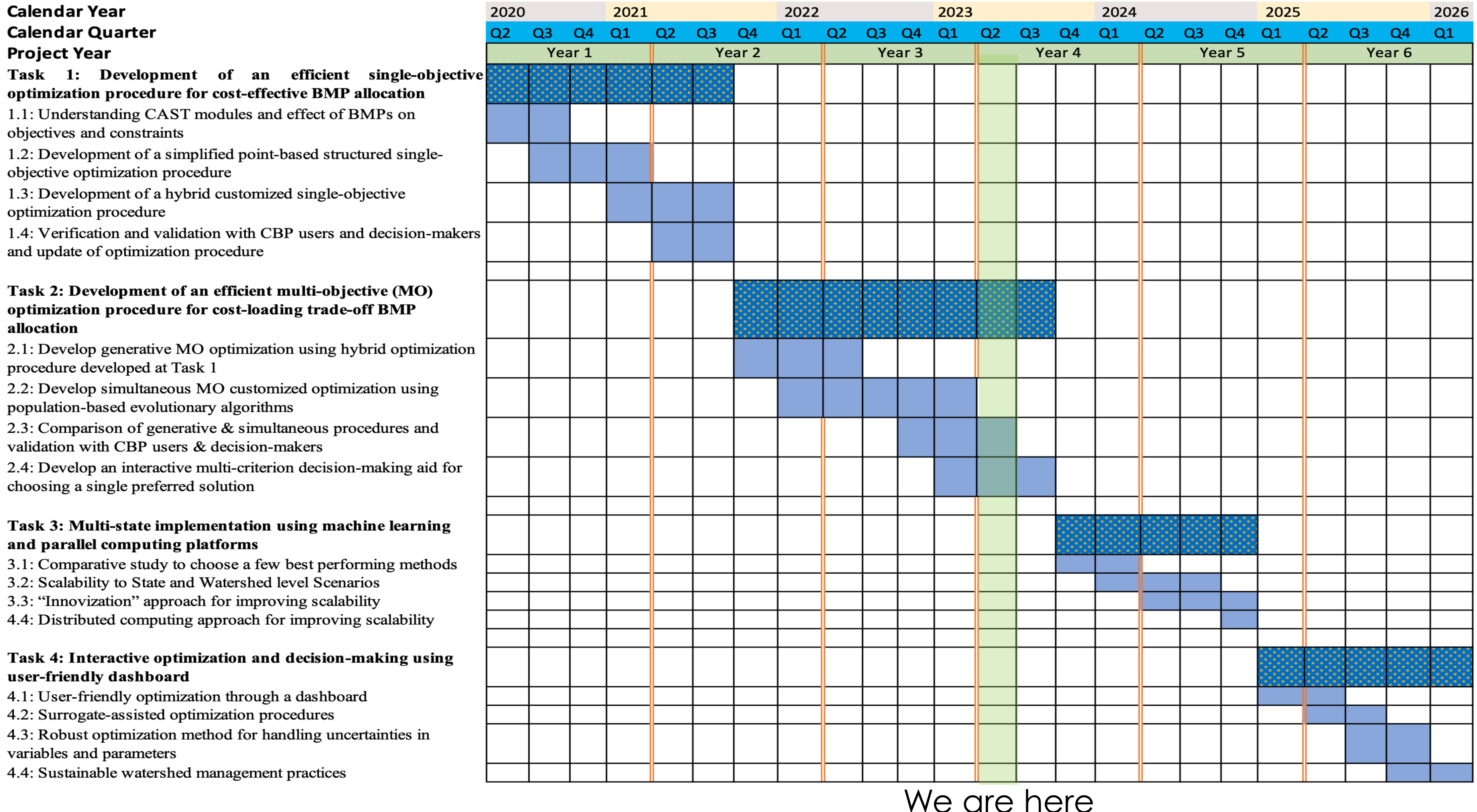
Objective of the MSU-Optimization Project



Investigate, develop, program, verify, and implement an optimization system built around the CBP's CAST Model to:

- Improve the water quality
- At the lowest cost

Timeline of the Project



Timeline of the Project

Calendar Year	2020			2021				2022				2023				2024				2025				2026
Calendar Quarter	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
Project Yea																							'ear 6	

Task 1: optimization
1.1: Understa objectives anc
1.2: Developr objective opti
1.3: Developr optimization p
1.4: Verificati and update of

Task 2: Deve optimization allocation
2.1: Develop procedure dev
2.2: Develop population-ba
2.3: Comparis validation wit
2.4: Develop choosing a si

Task 3: Mult and parallel
3.1: Compara
3.2: Scalabilit
3.3: "Innoviza
4.4: Distribut

Task 4: Inte user-friendly
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

Task 2: Development of an efficient multi-objective (MO) optimization procedure for cost-loading trade-off BMP allocation

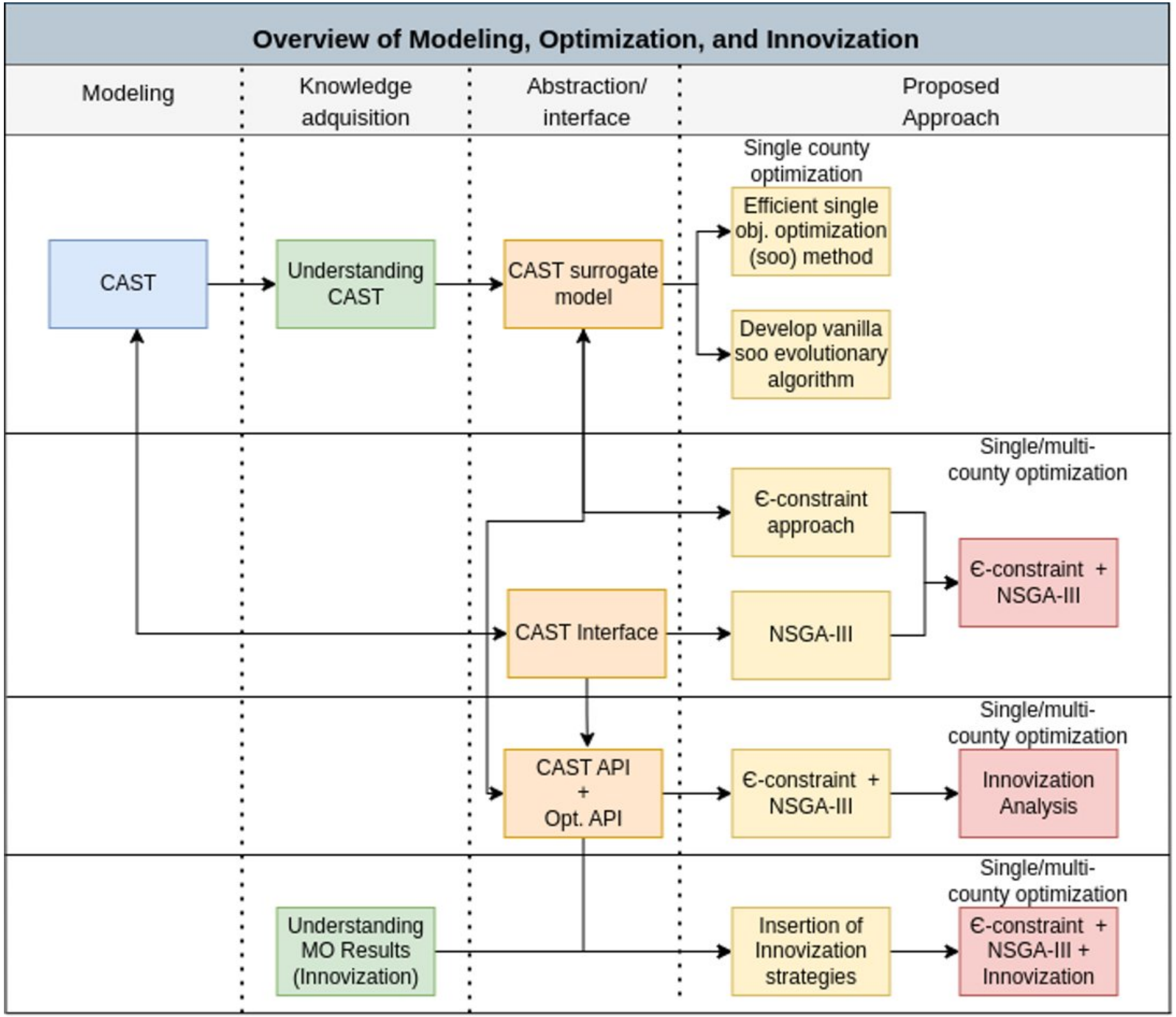
2.1: Develop generative MO optimization using hybrid optimization procedure developed at Task 1

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

We are here


Overview of Modeling, Optimization, and Innovization
Modeling
Knowledge adquisition
Abstraction/ interface
Proposed Approach
Single county optimization
CAST
Understanding CAST
CAST surrogate model
Efficient single obj. optimization (soo) method
Develop vanilla soo evolutionary algorithm
Single/multi-county optimization
Є-constraint approach
Є-constraint + NSGA-III
CAST Interface
NSGA-III
Single/multi-county optimization
CAST API + Opt. API
Є-constraint + NSGA-III
Innovization Analysis
Single/multi-county optimization
Understanding MO Results (Innovization)
Insertion of Innovization strategies
Є-constraint + NSGA-III + Innovization

Performed experiments

1. Efficiency BMPs
2. Land Conversion BMPs
3. Animal BMPs
4. Land conversion (first) and efficiency BMPs (second)
5. Efficiency BMPs (first) and the land conversion (second)
6. Mixed: Efficiency + land conversion
7. Bi-level: LC (upper level) and efficiency BMPs(lower level)
8. Efficiency + Land conversion + animal

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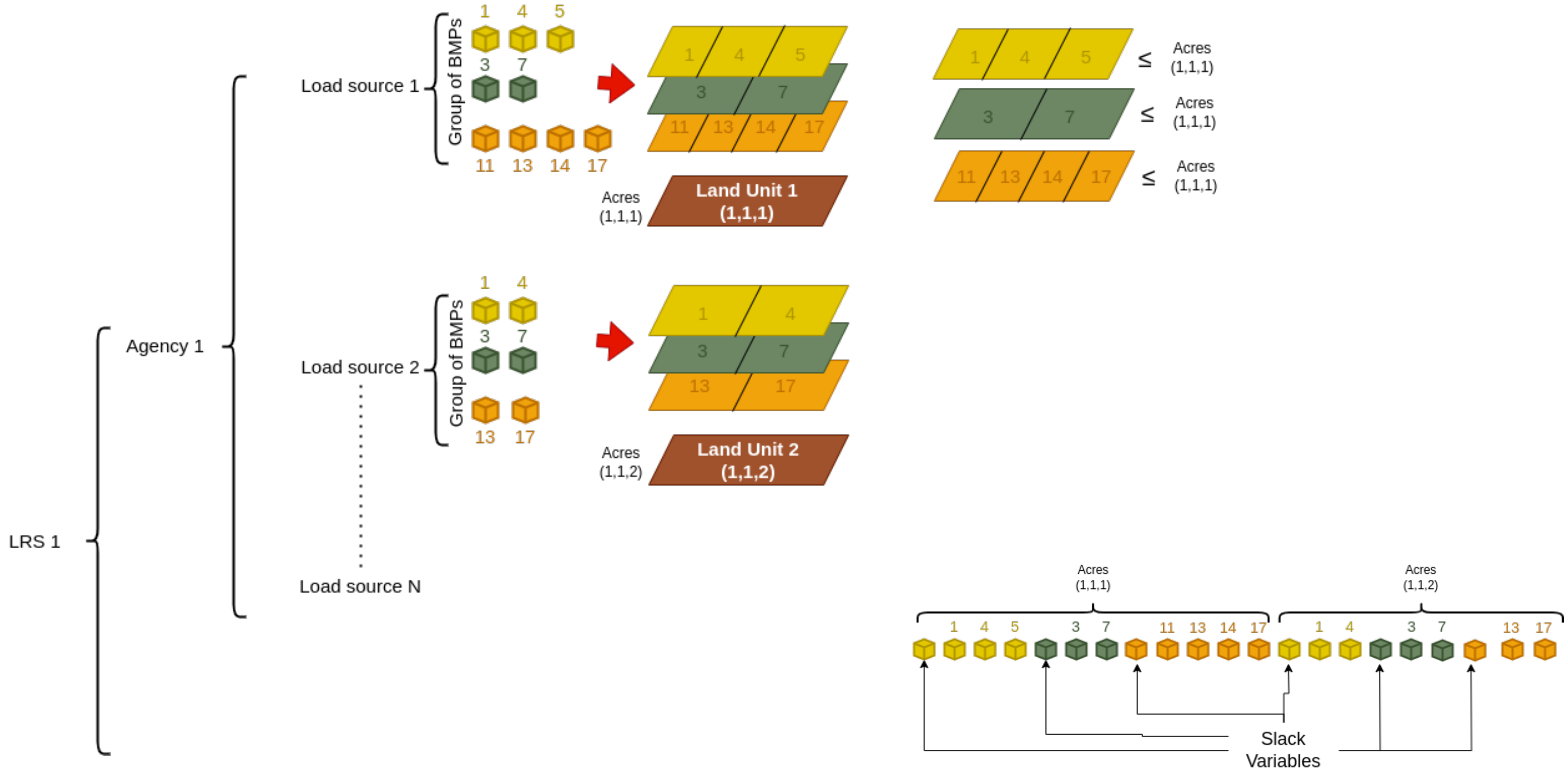
Efficiency BMPs



2 Land Conversion BMPs

- **Acres of a particular load source are converted into acres of another load source.**

Two options:

- The simplest option, the change only modifies the area for the two load sources involved in the conversion
- The change has an explicit side effect, which consists in removing additional loads generated in upland acres.

Land Conversion BMPs

2 Land Conversion BMPs

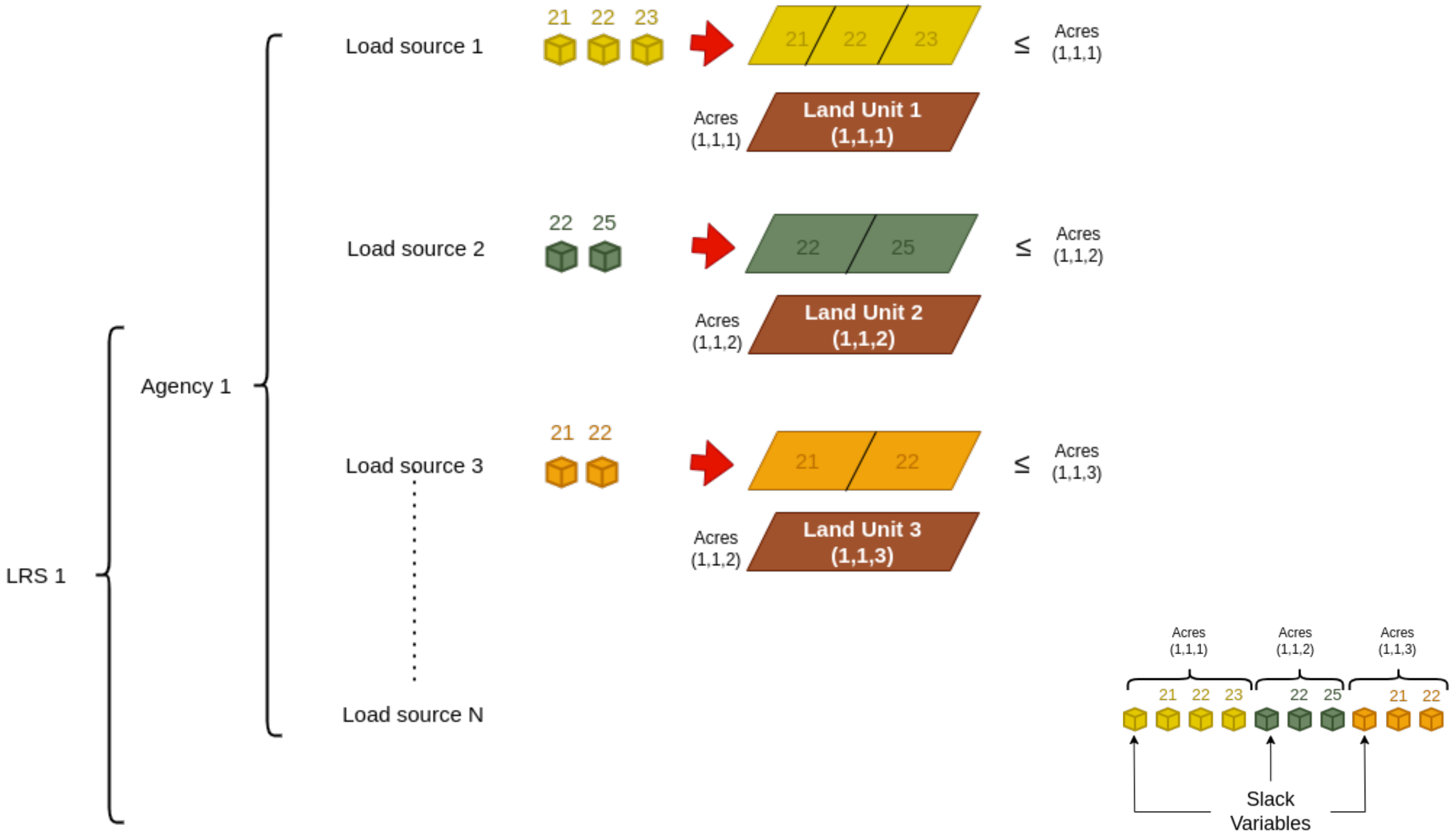
- Raise in the variable counter
- ~10% of increment in variables
- Introduces a significant level of epistasis*.
- We use CoreCAST to compute the load.

County	Eff. Variables	L.C. Variables
Berkeley	14,090	1,465
Grant	25,228	1,913
Hampshire	12,783	1,392
Hardy	18,607	1,909
Jefferson	12,303	1,374
Mineral	20,260	1,745
Monroe	3,102	352
Morgan	11,880	1,253
Pendleton	33,083	2,869
Preston	1,470	138
Tucker	1,012	50
Total	153,818	15,700

2 Land Conversion BMPs

- When the LC BMPs are introduced into the system, the behavior of the system is different. BMPs that previously were very effective for previous scenarios might no longer work.
- The representation of a solution is important in optimization problem-solving because it determines how the problem space is explored and the range of potential solutions considered
- A good representation ensures feasibility, enables efficient search, facilitates evaluation, and may need to be interpretable. It influences the effectiveness and quality of the optimization process.
- They way that L.C. BMPs work, required a customized representation of solutions in our approach.

2 Land Conversion BMPs

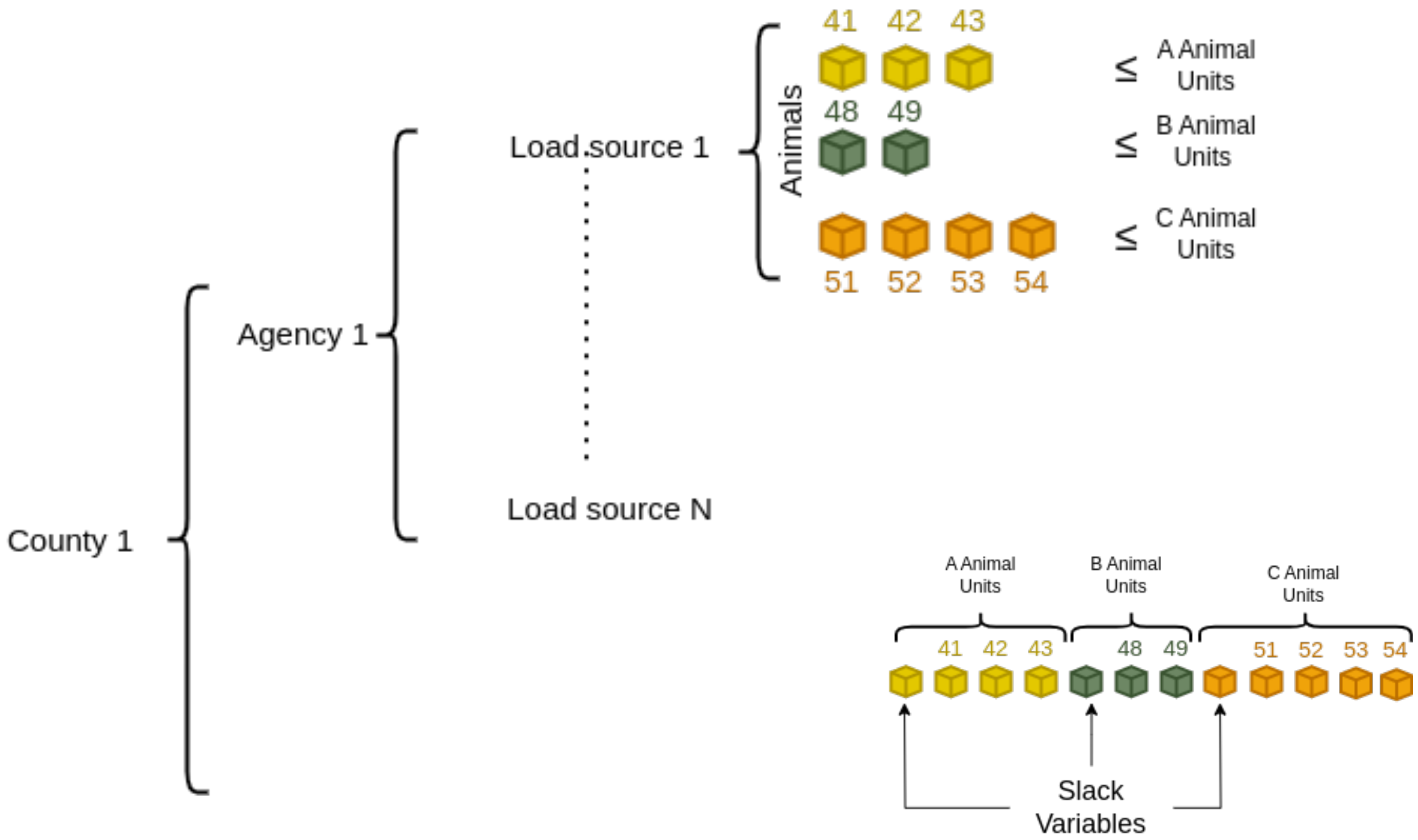


3 Animal BMPs

- Options that remove load from upland load sources *
  - These BMPs modify nutrient concentrations in animal manure for specific types, groups, and number of animals.
  - These BMPs are only applied to Feeding Space load sources and may have side effects on fertilizer application and atmospheric deposition.
  - The total number of animals is only available at the county level.

*We use CoreCAST to compute the load.

3 Animal BMPs



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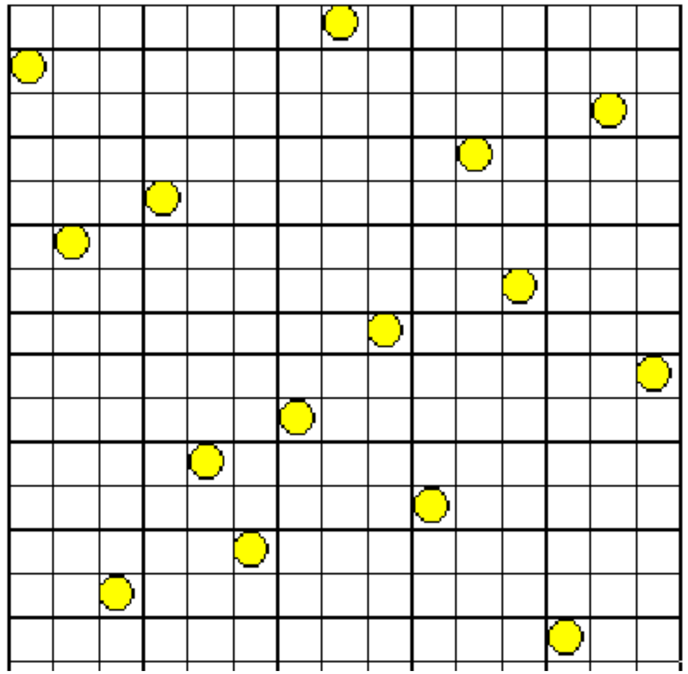
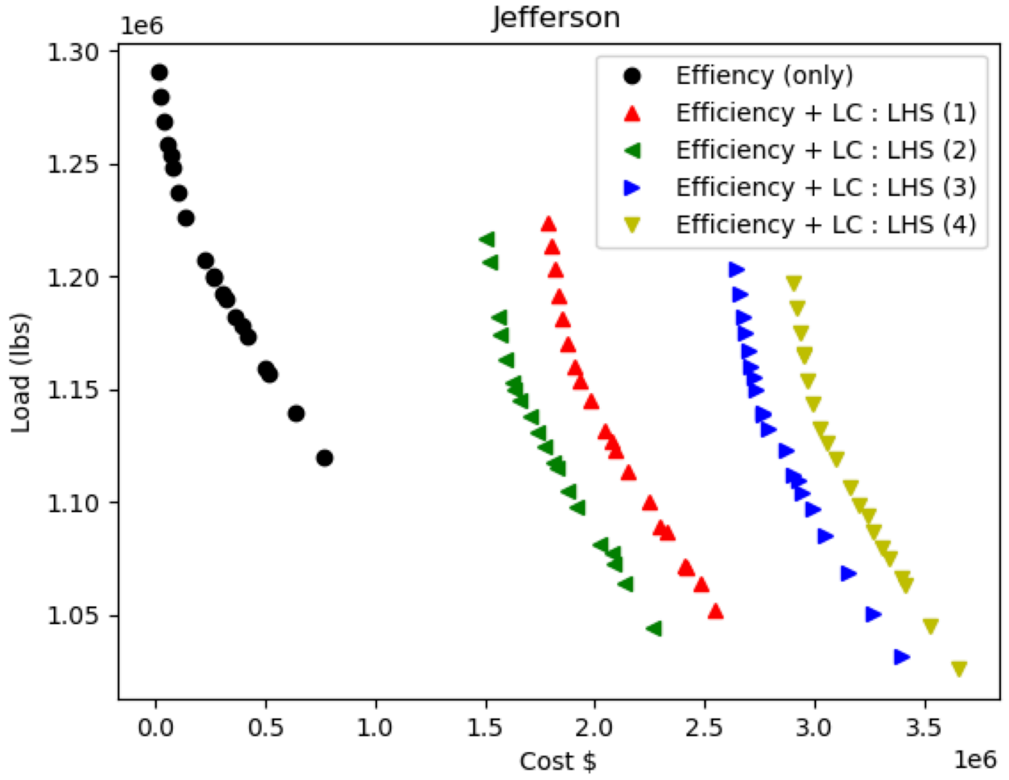
Land Conversion (first) and Efficiency (second)

- Experiment
  - Latin Hypercube Sampling statistical method where the range of each variable is divided into equally probable intervals.
  - One value from each interval is chosen at random to construct the sample, ensuring a good spread across the range of each variable.
  - Create 100 solutions using LHS. Each solution refers to a vector containing the number of LC BMPs.



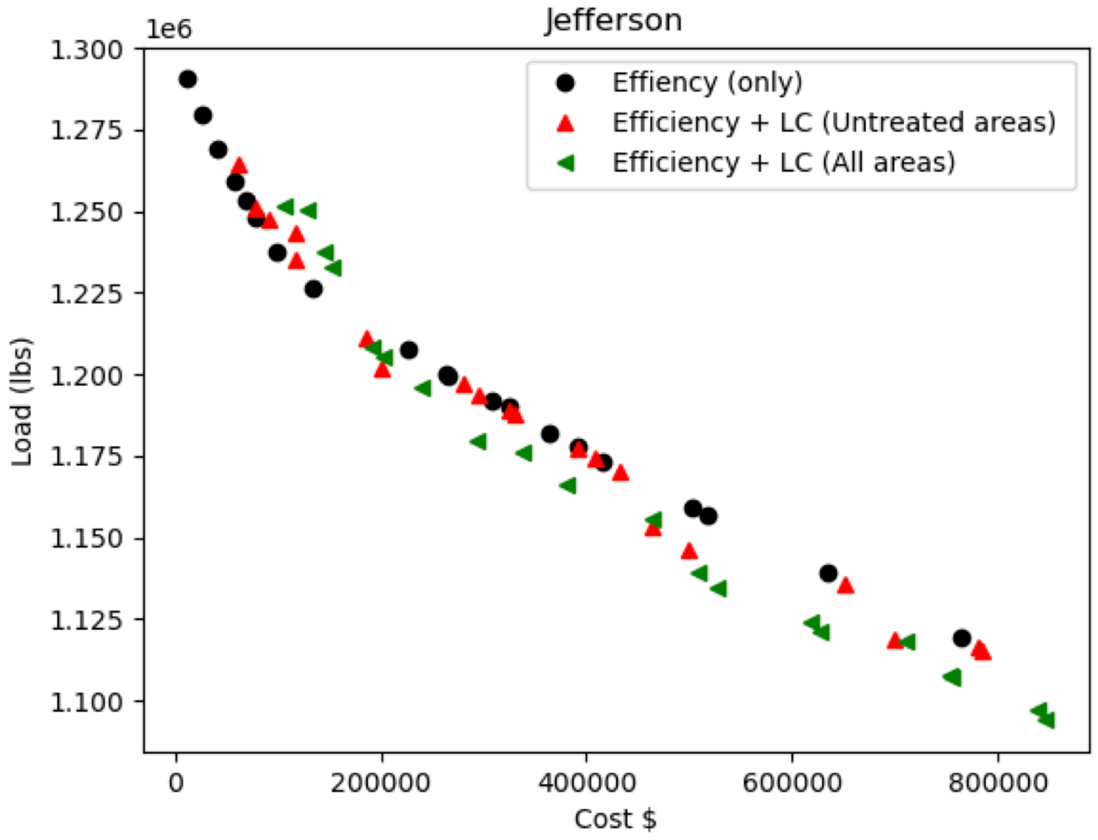
4 Land Conversion (first) and Efficiency (second)

- Experiment
  - Create a Latin Hypercube Sampling (LHS) for the given LC BMPs
  - Optimize efficiency BMPs on each LHS solution
- Conclusions
  - The High epistasis prevents the approach to obtain good results.
  - Large scale dimensionality.
  - Optimization is needed.



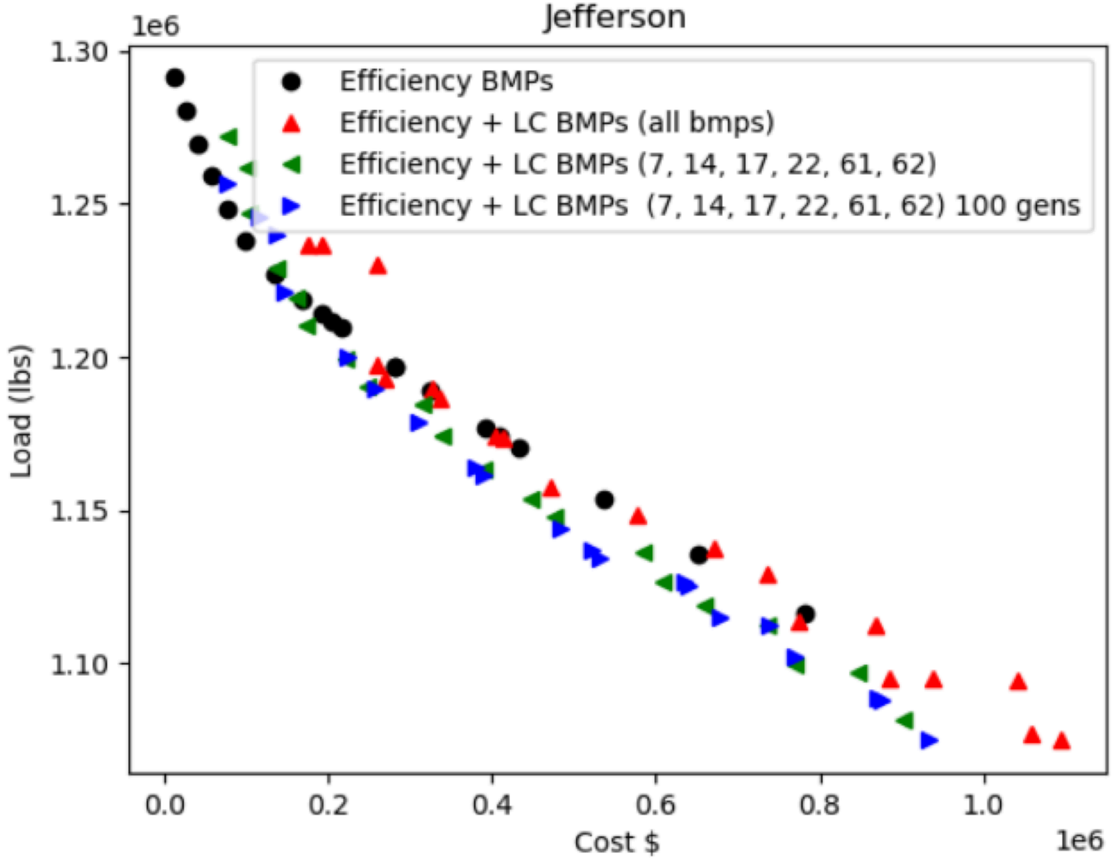
5 Efficiency (first) and Land Conversion (second)

- We optimize efficiency BMPs in the usual way
- We optimize for land conversion in two different ways.
  - We only look to use LC BMPs on non selected parcels by the optimization of efficiency BMPs. Good results here would indicate that we can separate the problems (LC and efficiency).
  - We apply LC BMPs to any parcel
- Results:
  - Although both approaches produced results better than using efficiency BMPs (only), it is clear that the second approach produced better results. Therefore, we cannot separate the optimization of LC BMPs and efficiency BMPs.



6 Mixed: Efficiency and Land Conversion

- We first find a solution with Efficiency BMPs, then we optimize simultaneously efficiency and land conversion BMPs.
- We found that trying to optimize simultaneously efficiency and LC BMPs is time consuming.
- We added an additional experiment, where we selected one single LC BMP at a time to optimize with the efficiency ones. We found that some LC BMPs offer a very good response, and that the problem gets more difficult when we add more variables.
- The execution for an extended number of generations produce better results.
- We will need to extend our innovization study to the use of LC BMPs.



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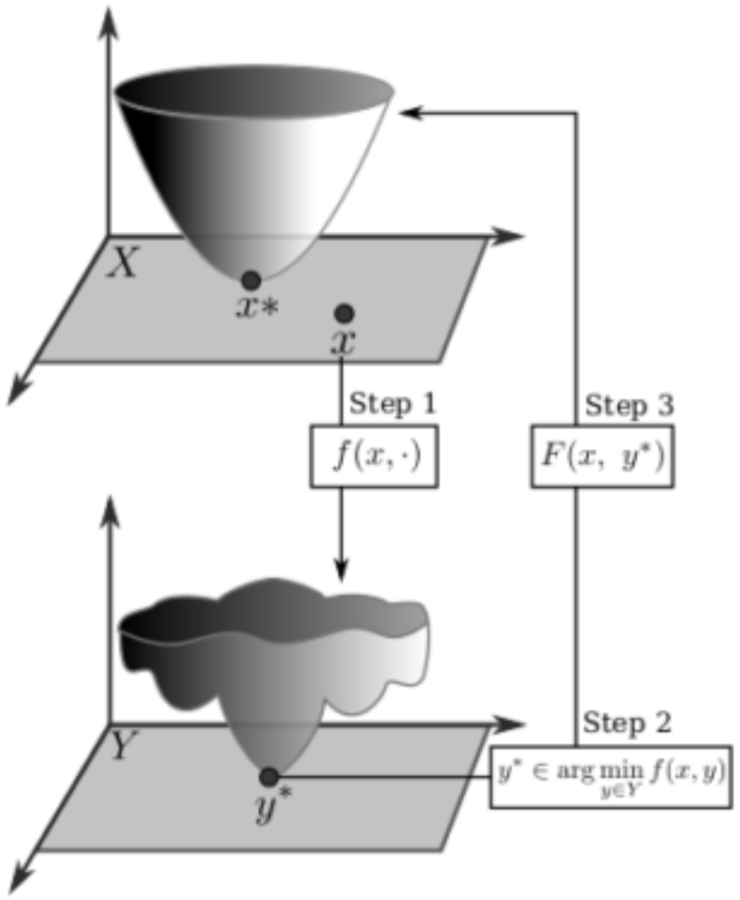
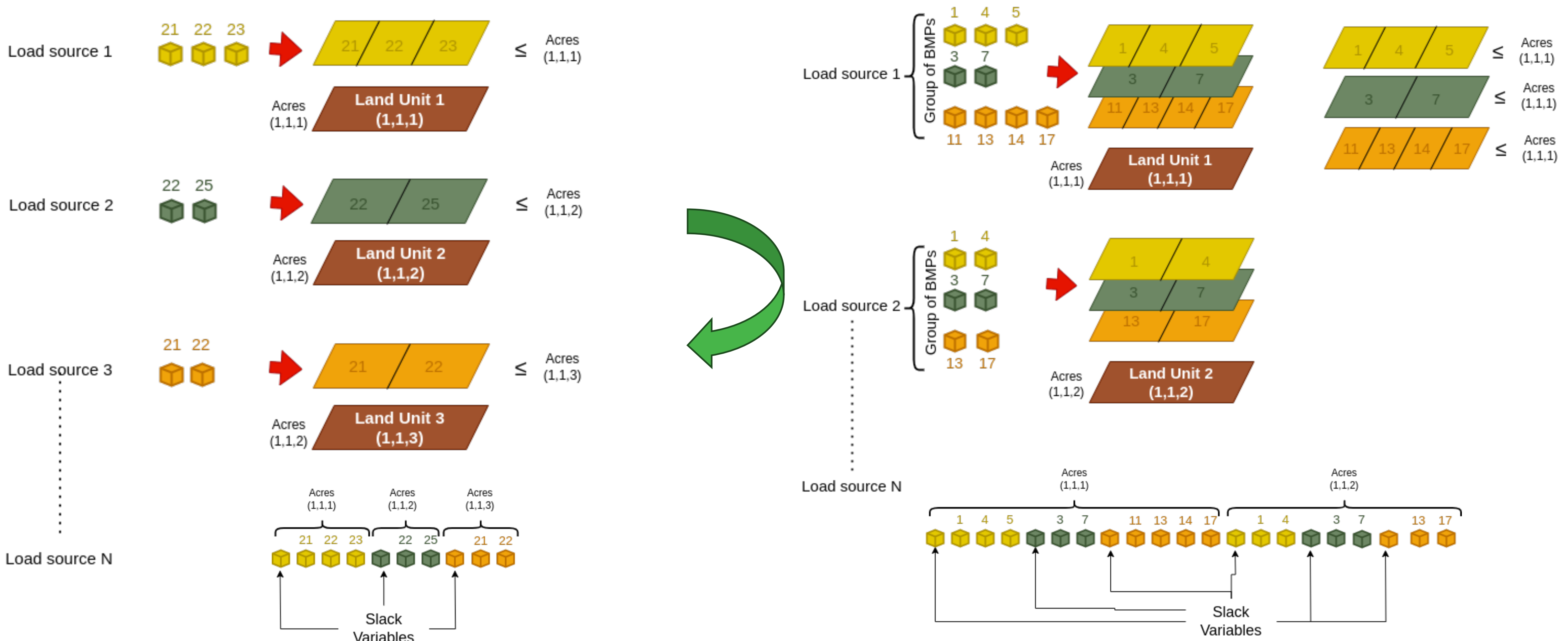
Bi-level: LC (upper level) and efficiency BMPs(lower level)

- Bilevel optimization refers to a type of optimization problem where one problem is embedded within another.
- It is an optimization problem that has two levels of optimization - a "upper" level and a "lower" level.
- Each level has its own objective function and constraints.
- These types of problems often arise in scenarios where there are nested decision-making processes.

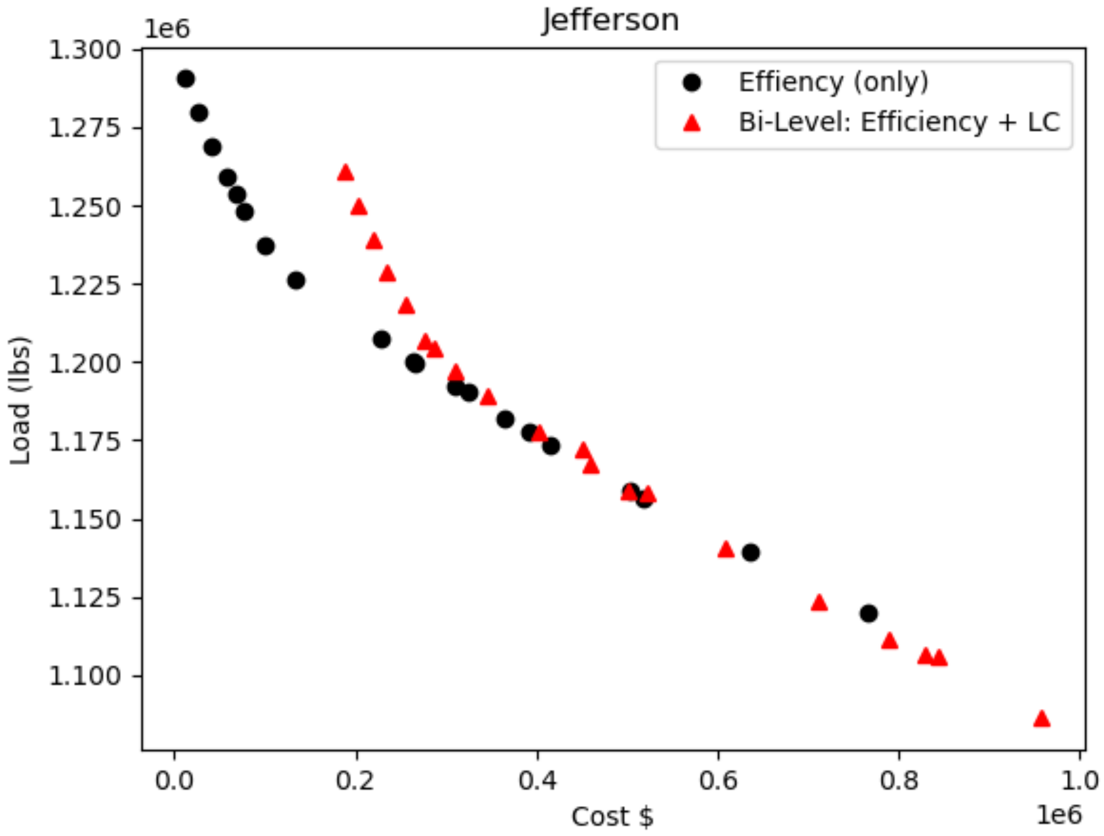


7 Bi-level: LC (upper level) and efficiency BMPs(lower level)



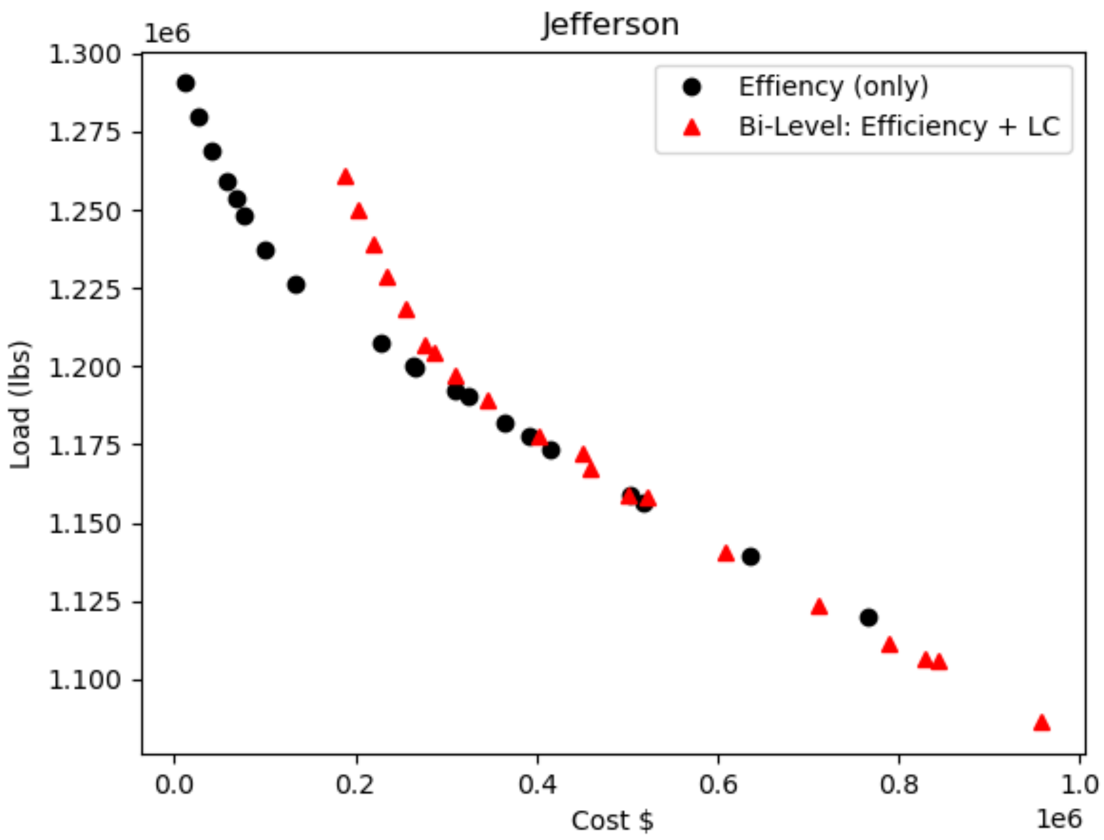
7 Bi-level: LC (upper level) and efficiency BMPs(lower level)

- We are still in the proof of concept.
- LC BMPs are executed in CoreCAST.
- Efficiency BMPs executes the surrogate model.
- The proof of concept consist of:
  1. Create an initial population using LHS.
  2. Each solution is optimized using our epsilon constraint approach.
  3. We merge all solutions and use non-dominance to select a fixed number of solutions.
  4. The fitness of a solution depends on their solutions contributed to the global front.
  5. We apply genetic operator to such solutions
  6. If max number of geneations has reached, go to step 8.
  7. Go to step 2.
  8. Exit.



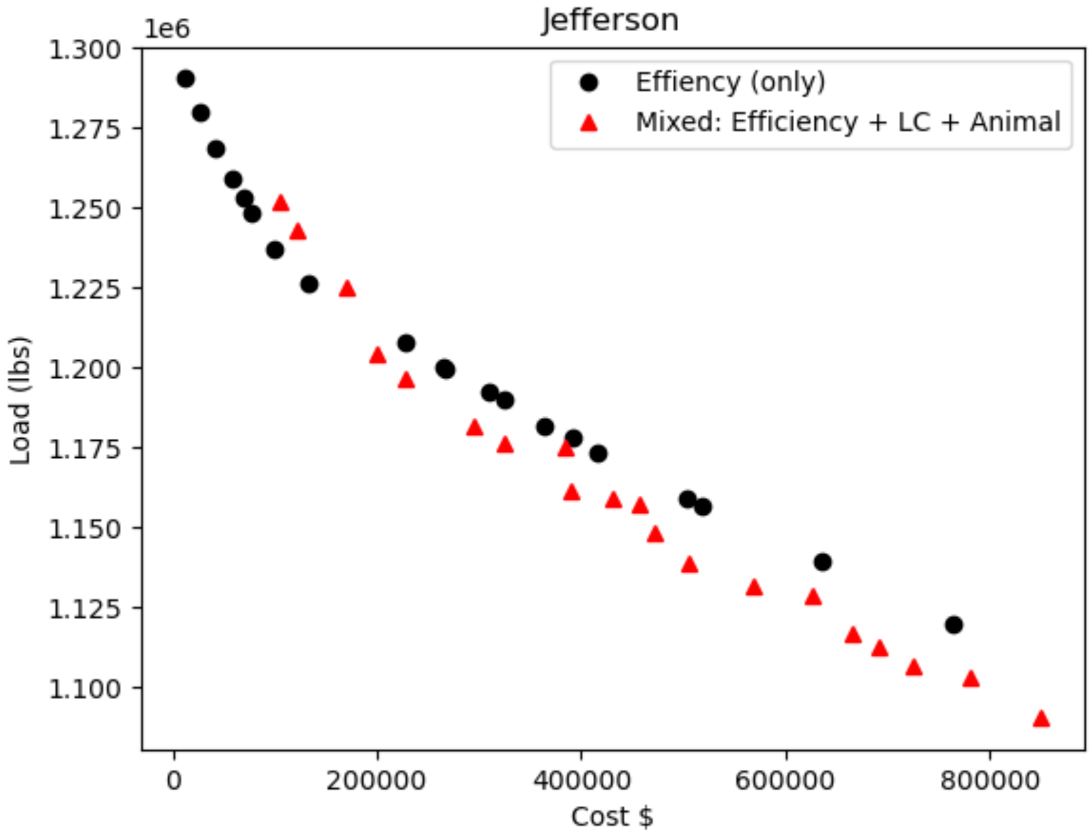
7 Bi-level: LC (upper level) and efficiency BMPs(lower level)

- This is a promising approach. However, it is computationally expensive.
- We use the surrogate model to prevent the excessive call to CoreCAST
- We will present results of this technique in the next quarterly meeting.



8 Efficiency + Land Conversion + Animal BMPs

- We adopted animal units to gather most animal types.
- We have a low number of added variables per county.
- It is possible to optimize Animal BMPs independently of Efficiency + LC BMPs.



Conclusions:

LC BMPs produce a significant reduction in loads, Mixed optimization produced the best results in our studies.

Bi-level optimization shows promising results. Reduction in the number of LC BMPs improve the performance of the approach.

Animal BMPs introduces little variables to the problem.
It is possible to optimize Animal BMPs independently.

Next steps:

More research regarding Bi-level optimization must be performed.

We shall extend our innovization study to LC BMPs.

We will continue our work on decision making.

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Computational Optimization and Innovation

Thank you

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