Modeling Workgroup Meeting
Quarterly Review

Optimization Update: Development of A Memetic Algorithm for Large-Scale Watershed Optimization

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MICHIGAN STATE UNIVERSITY

Agenda

- Optimization Problems and Methods
  - Single-objective, multi-objective, large-scale, robust, surrogate-assisted
- Objective 1: Understanding the CAST system and Development of an Efficient Single-objective Hybrid Optimization Procedure
  - April 1, 2020 to September 30, 2021 (18 months)
- Current Accomplishments

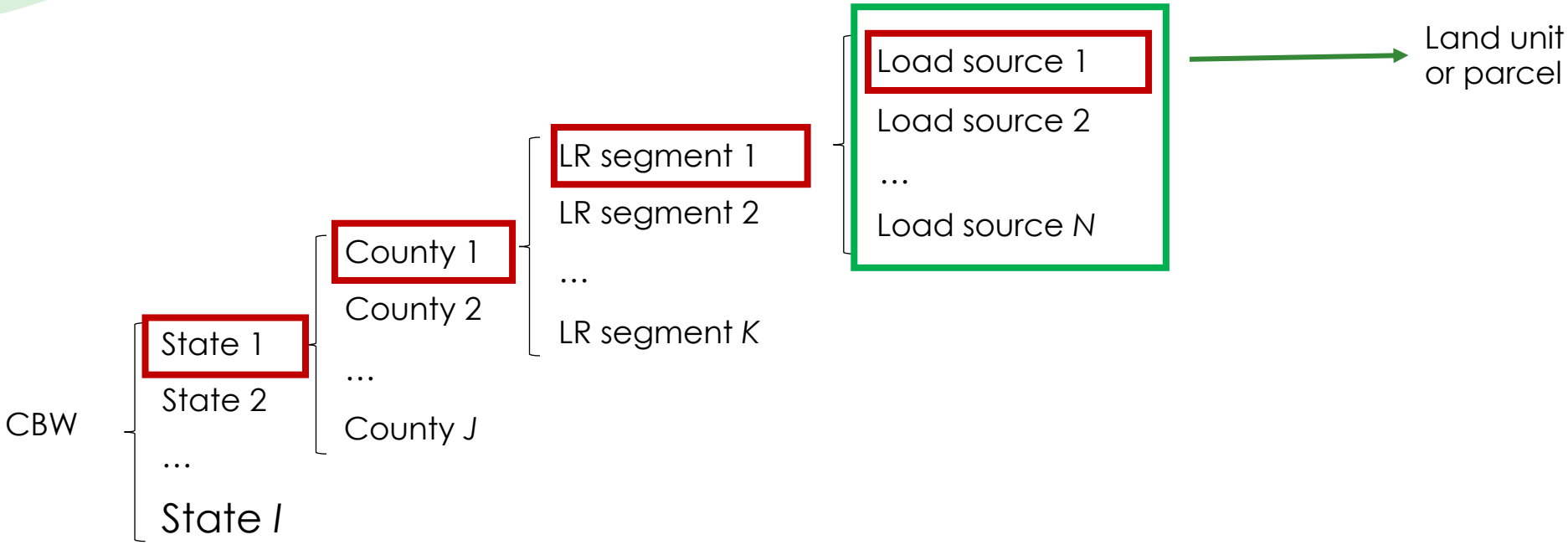
Objective 1: Understanding the CAST system and Development of an Efficient Single-objective Hybrid Optimization Procedure (April 1, 2020 to September 30, 2021)

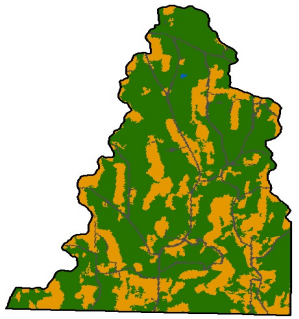
- Understanding CAST modules and effect of BMPs on objectives and constraints (Achieved)
- Development of a simplified point-based structured single-objective optimization procedure
  - Gradient-based IPOPT (ongoing)
- Development of a hybrid customized single-objective optimization procedure
  - Customized Genetic Algorithms (ongoing)
- Verification and validation with CBP users and decision-makers and update of optimization procedure (planned)

Accomplishments

1) Brief explanation of the variables of the problem and variable reduction.
2) Development of a simplified point-based structured single-objective optimization procedure (**OPT2**)
3) Development of a hybrid customized single-objective optimization procedure (**OPT3**)
4) Conclusions and future work

Spatial Hierarchy

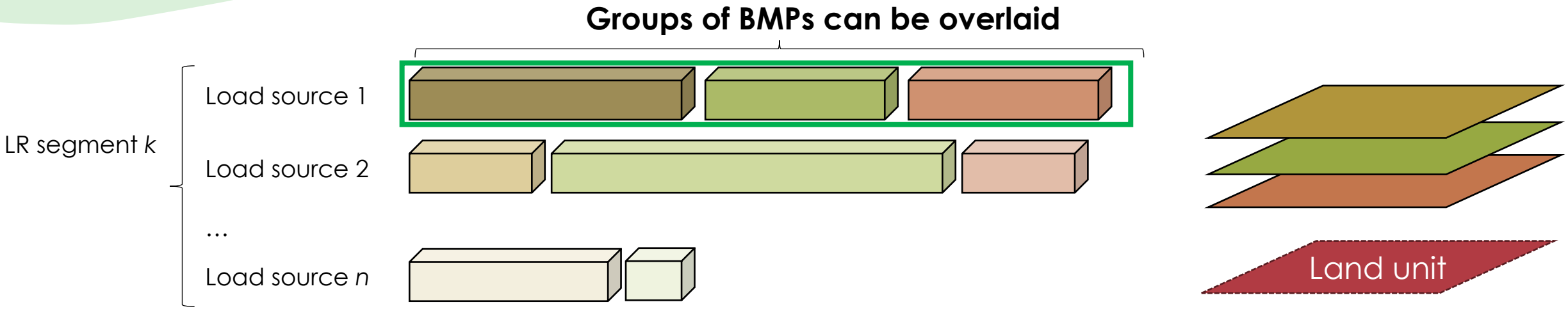


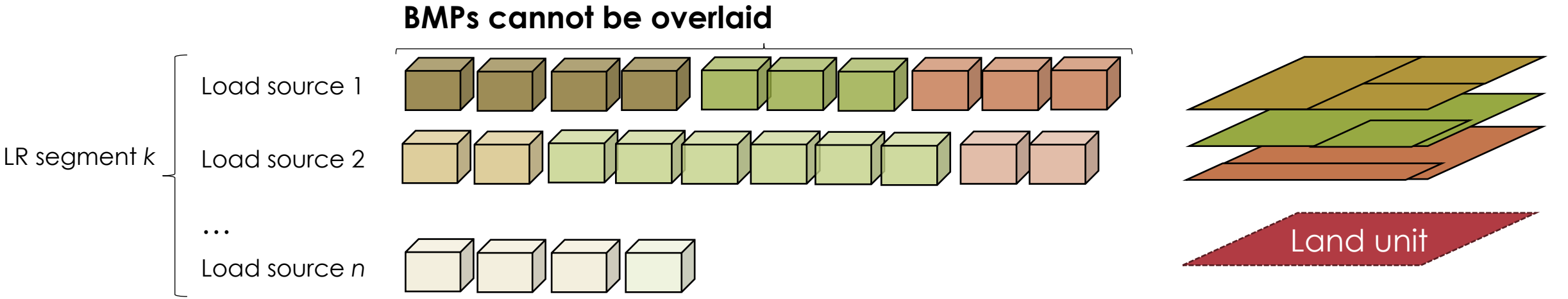


Natural
Agriculture
Water
Developed

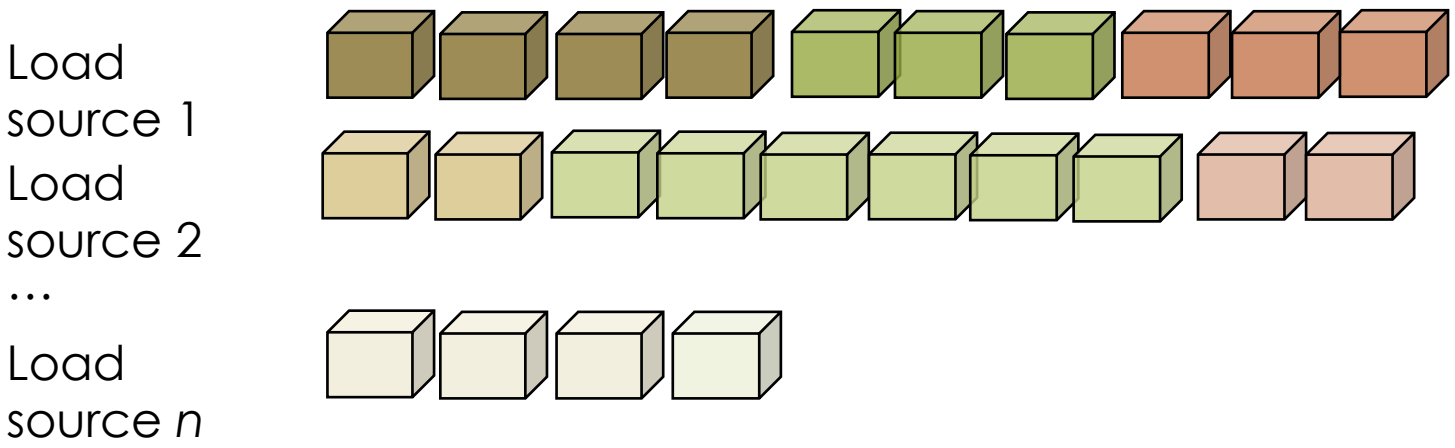
Livingston county, NY

Groups of BMPs



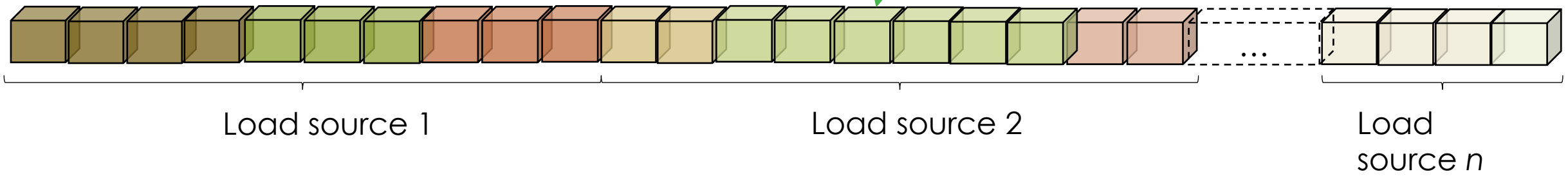


Decision Variables



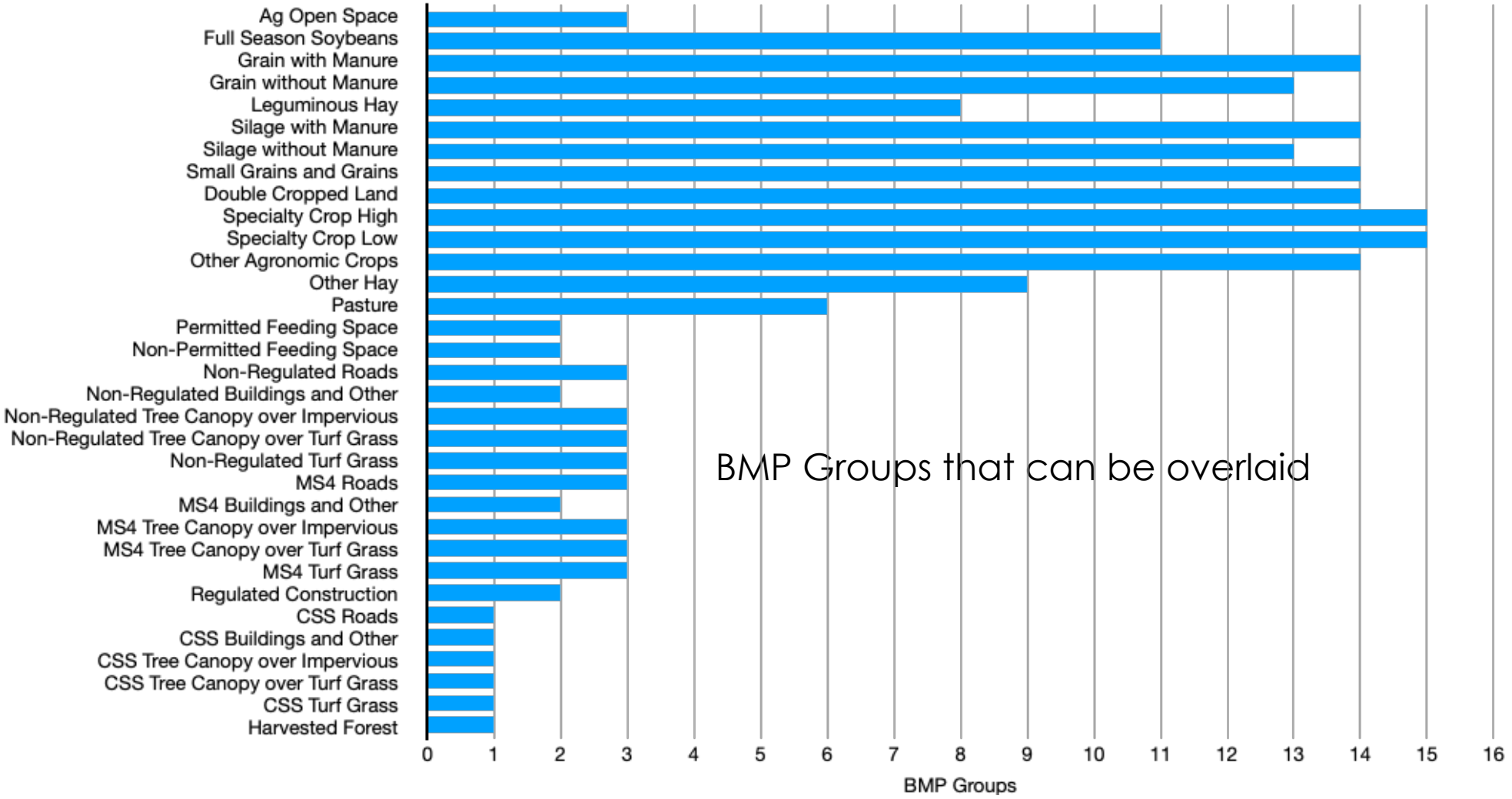
Vector of decision variables for <u>one LR Segment</u>:

Decision variable: size of each BMP (area, length, # units, etc.)



Vector of decision variables for <u>one county</u> <-- join vectors for LR segments within the county

Livingston, NY (33 load sources)

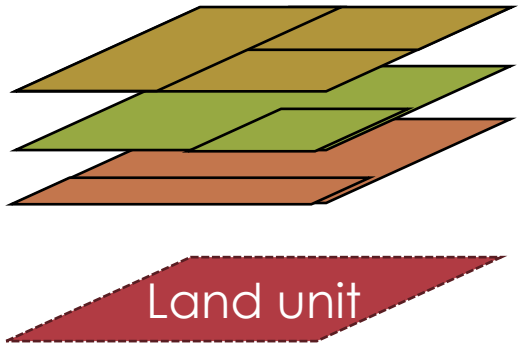


203 groups of BMPs

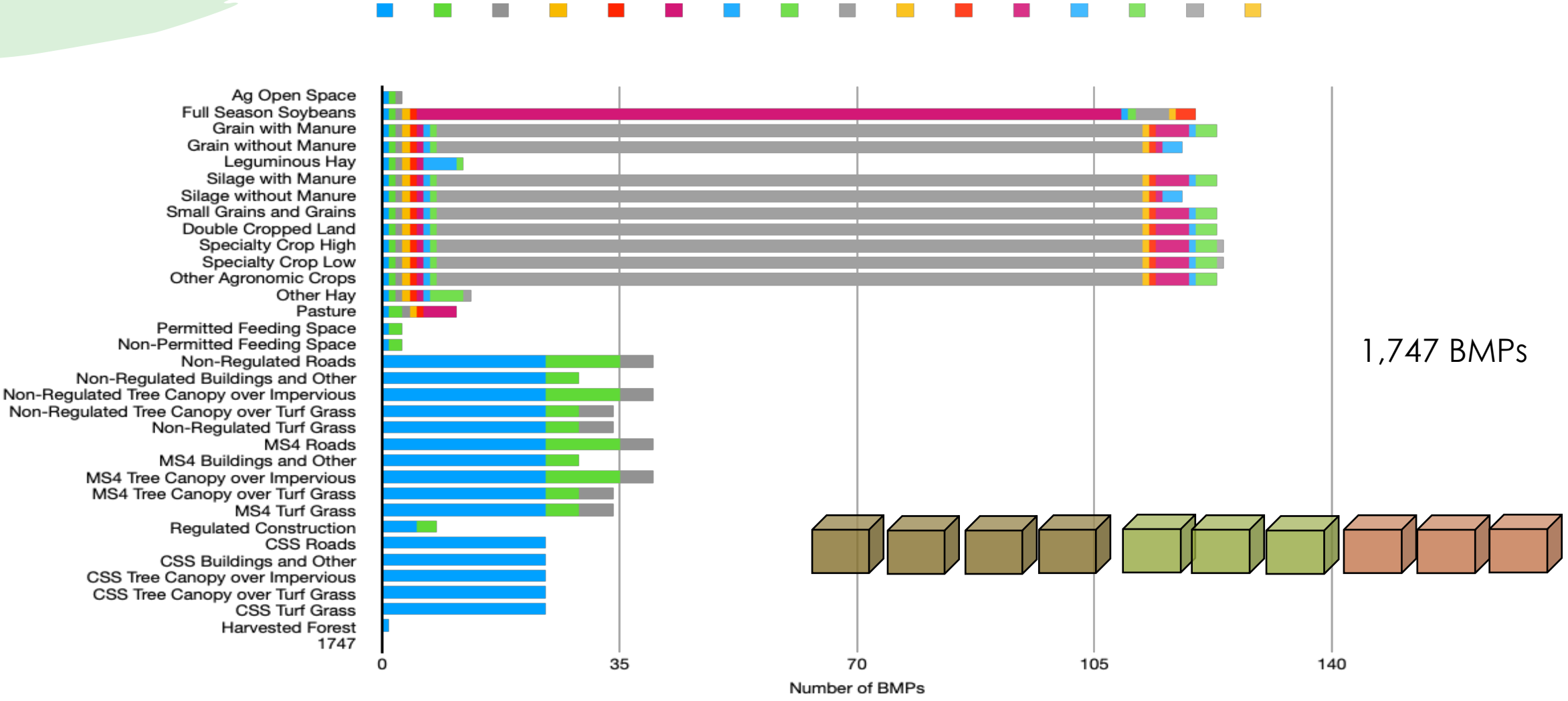
BMP Groups that can be overlaid

An example of BMP groups for the Regulated Construction Load Source

Group 1	Group 2
Nutrient Management Plan	Erosion and Sediment Control Level 1
Nutrient Management Plan High Risk Lawn	Erosion and Sediment Control Level 2
Nutrient Management Plan Low Risk Lawn	Erosion and Sediment Control Level 3
Nutrient Management Maryland Commercial Applicators	
Nutrient Management Maryland Do It Yourself	

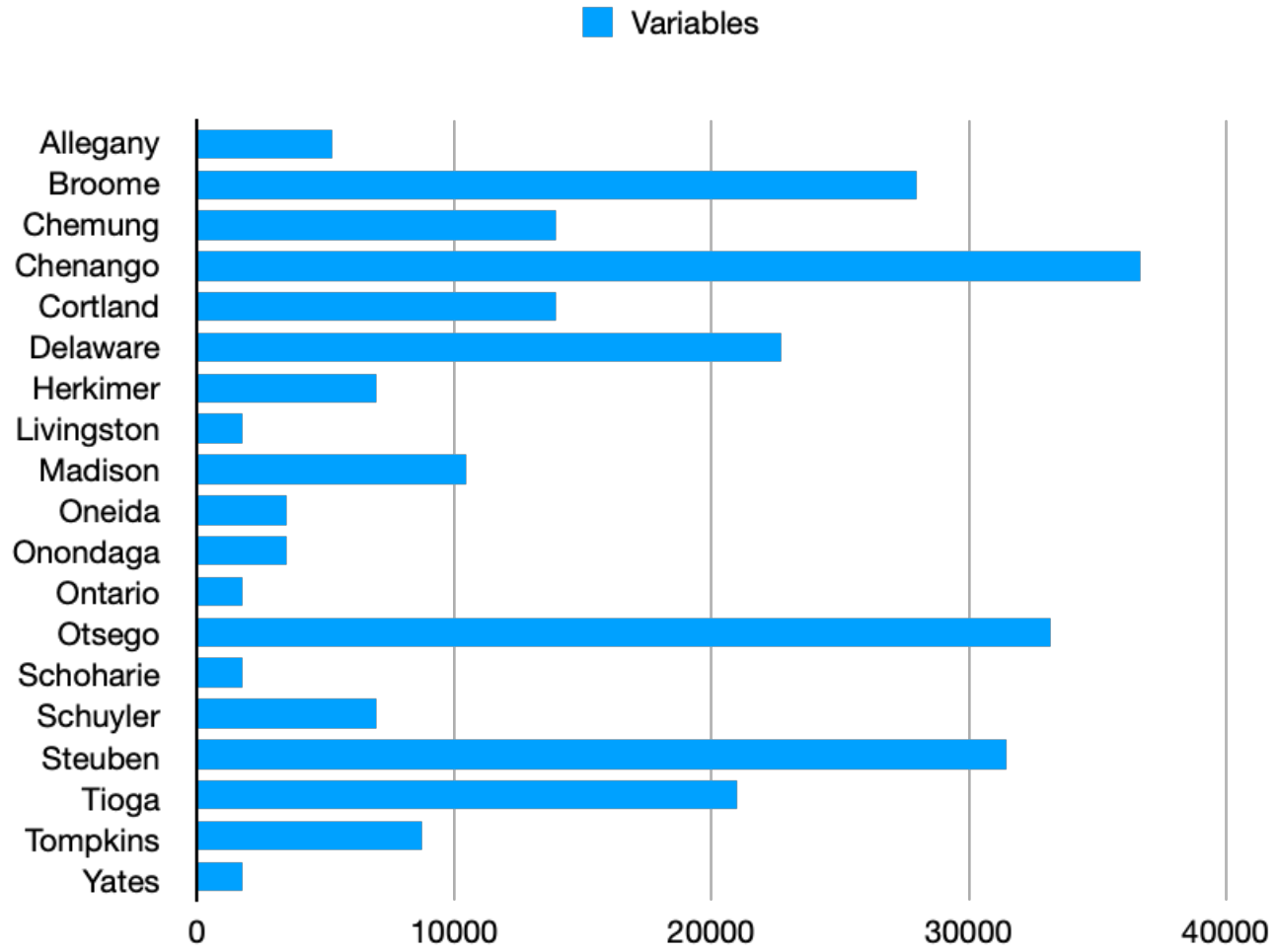


Expansion of variables: Livingston, NY



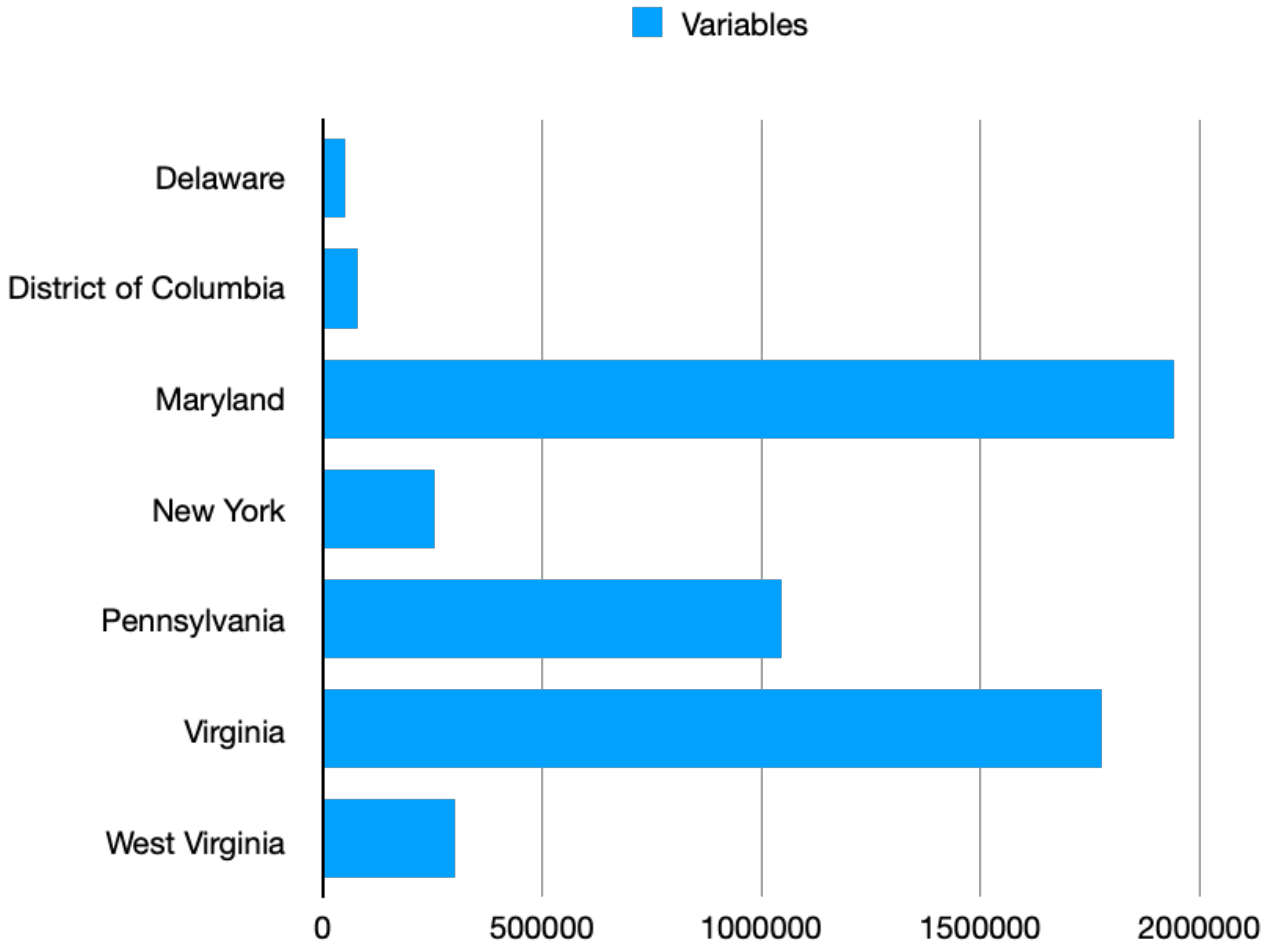
1,747 BMPs

Variables in New York (CBW)



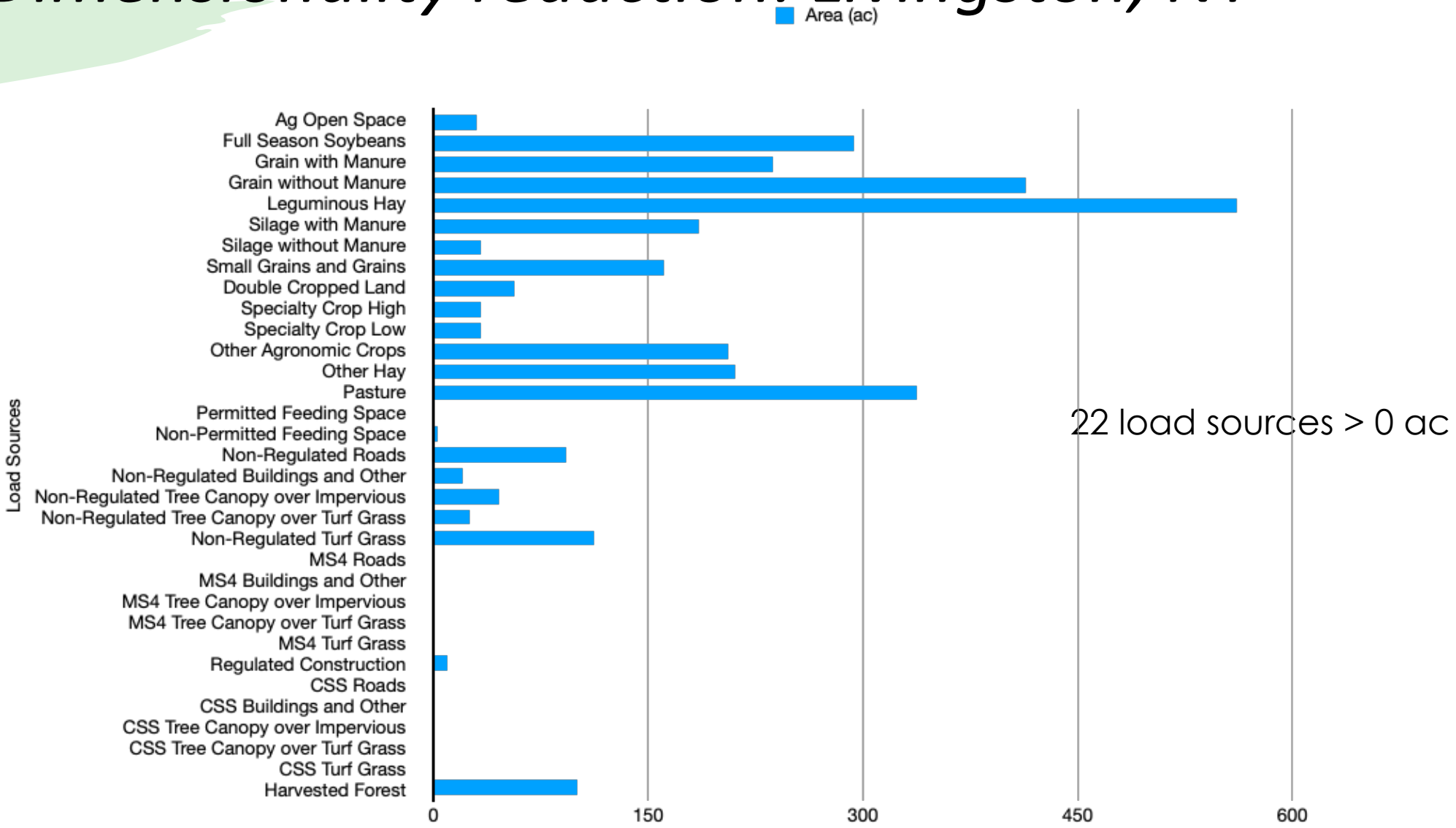
253,315 variables

Entire Watershed



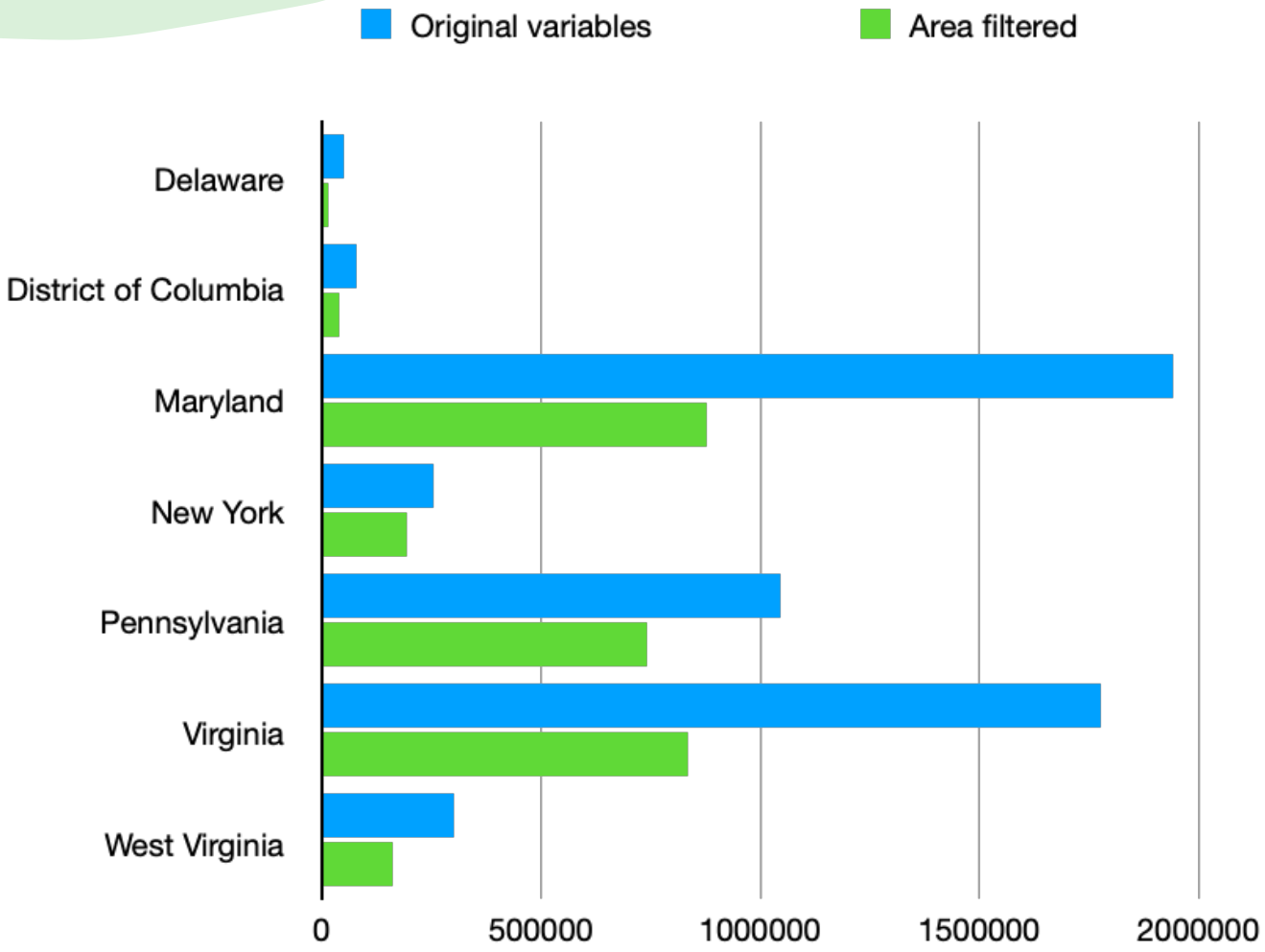
5,450,640 variables

Dimensionality reduction: Livingston, NY



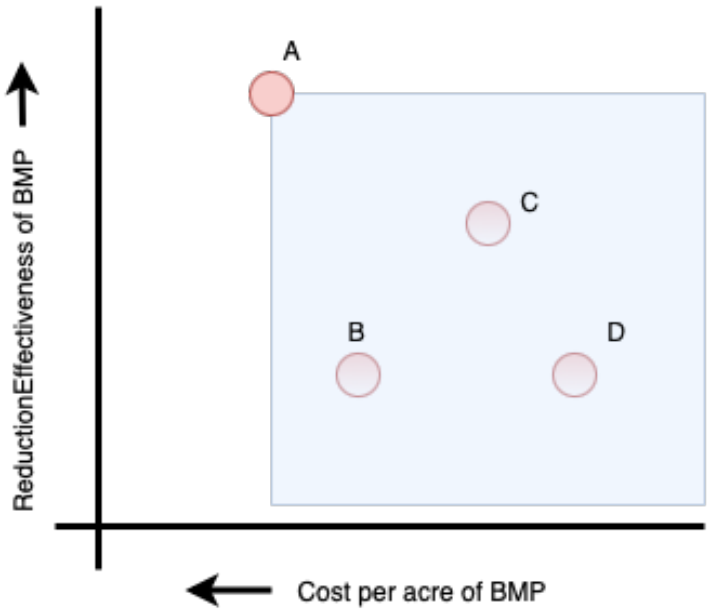
22 load sources > 0 ac

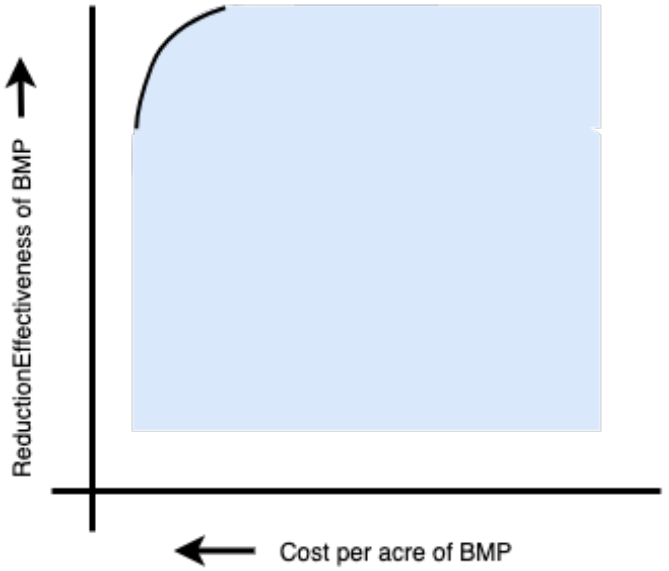
Comparison in the number of variables



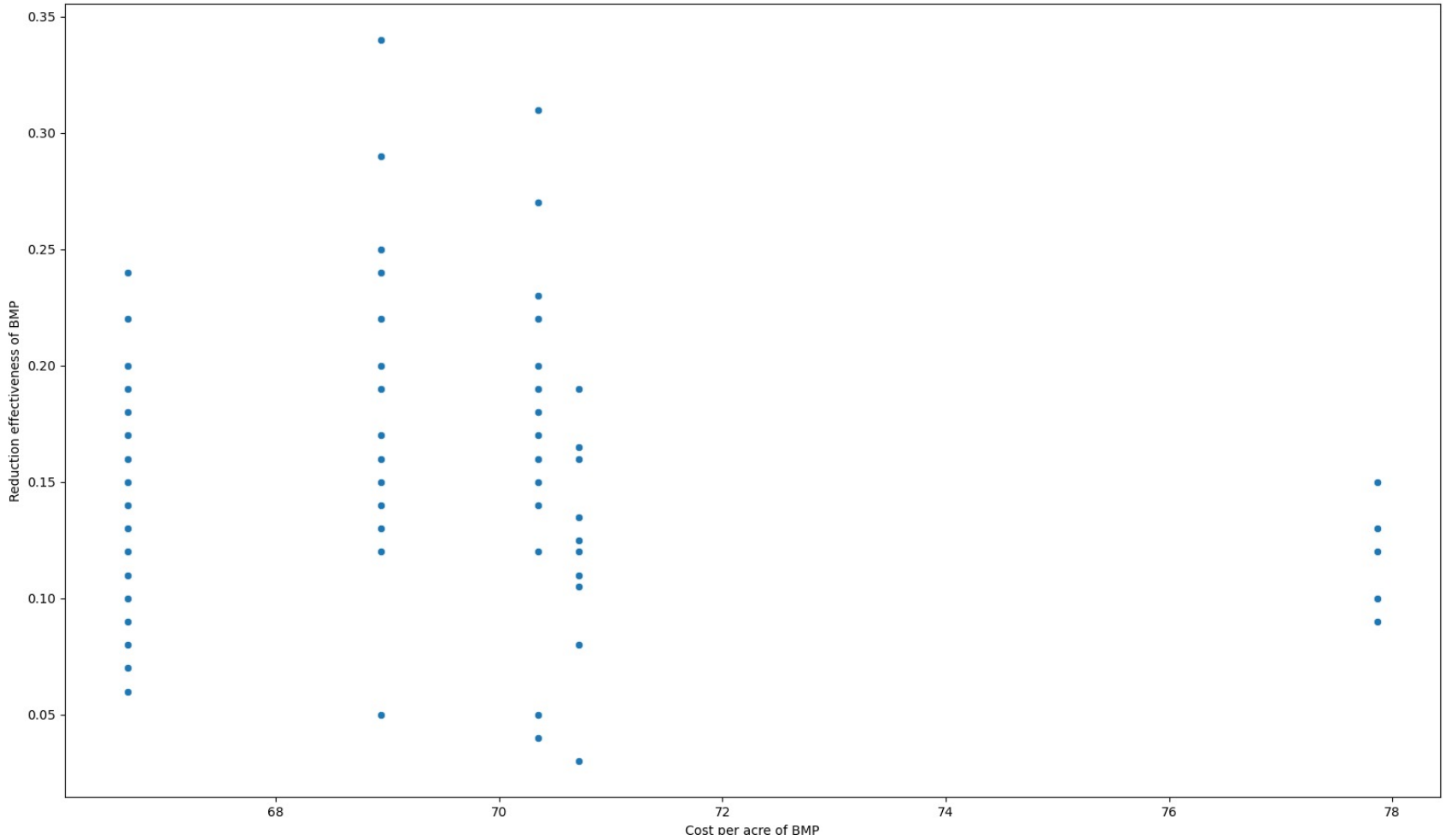
Reduction from
5,450,640 variables
to
2,848,469 variables
47%

Selecting efficient and nonefficient BMPs





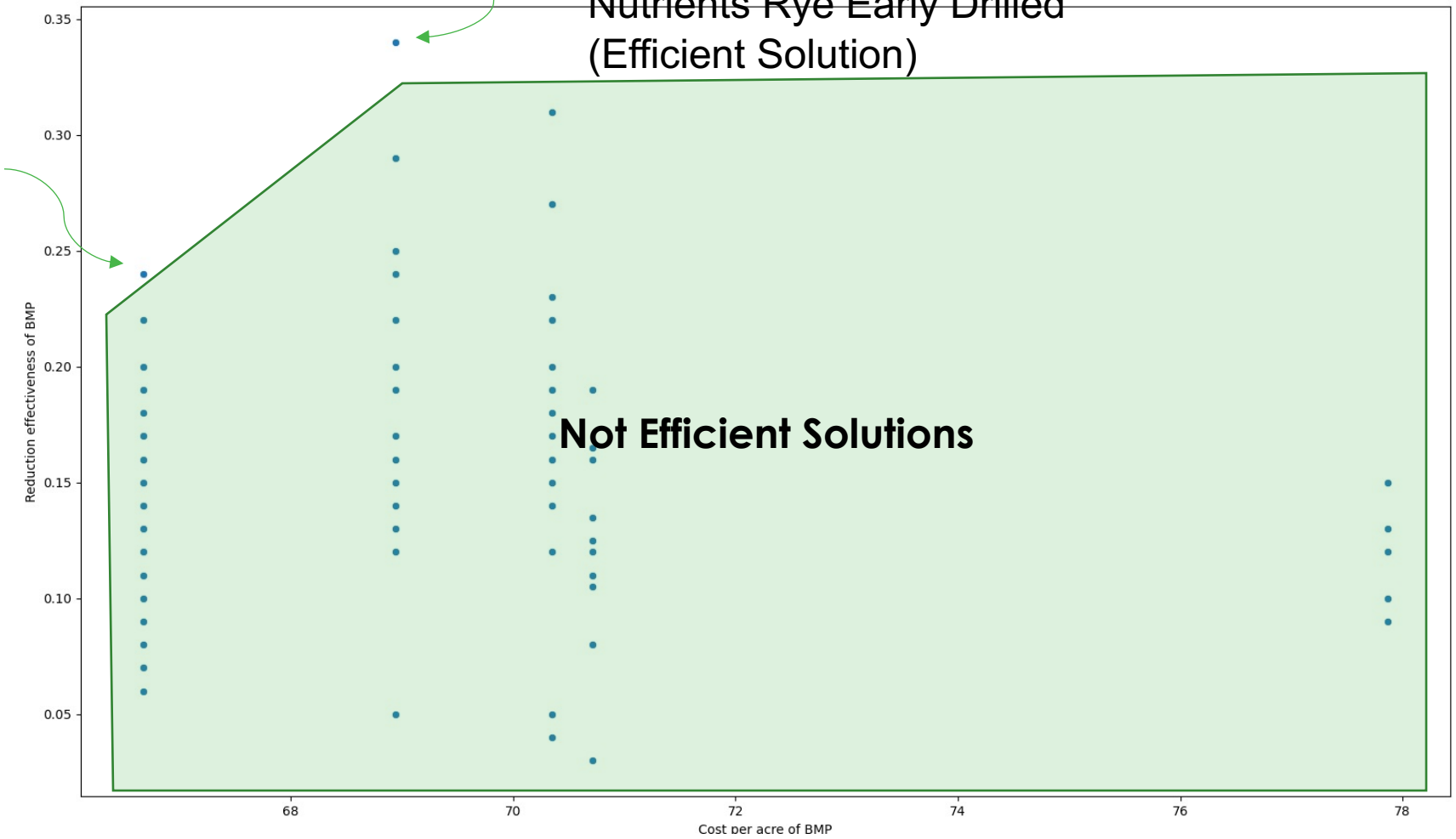
Example of reduction of dimensionality on Full Season Soybeans.



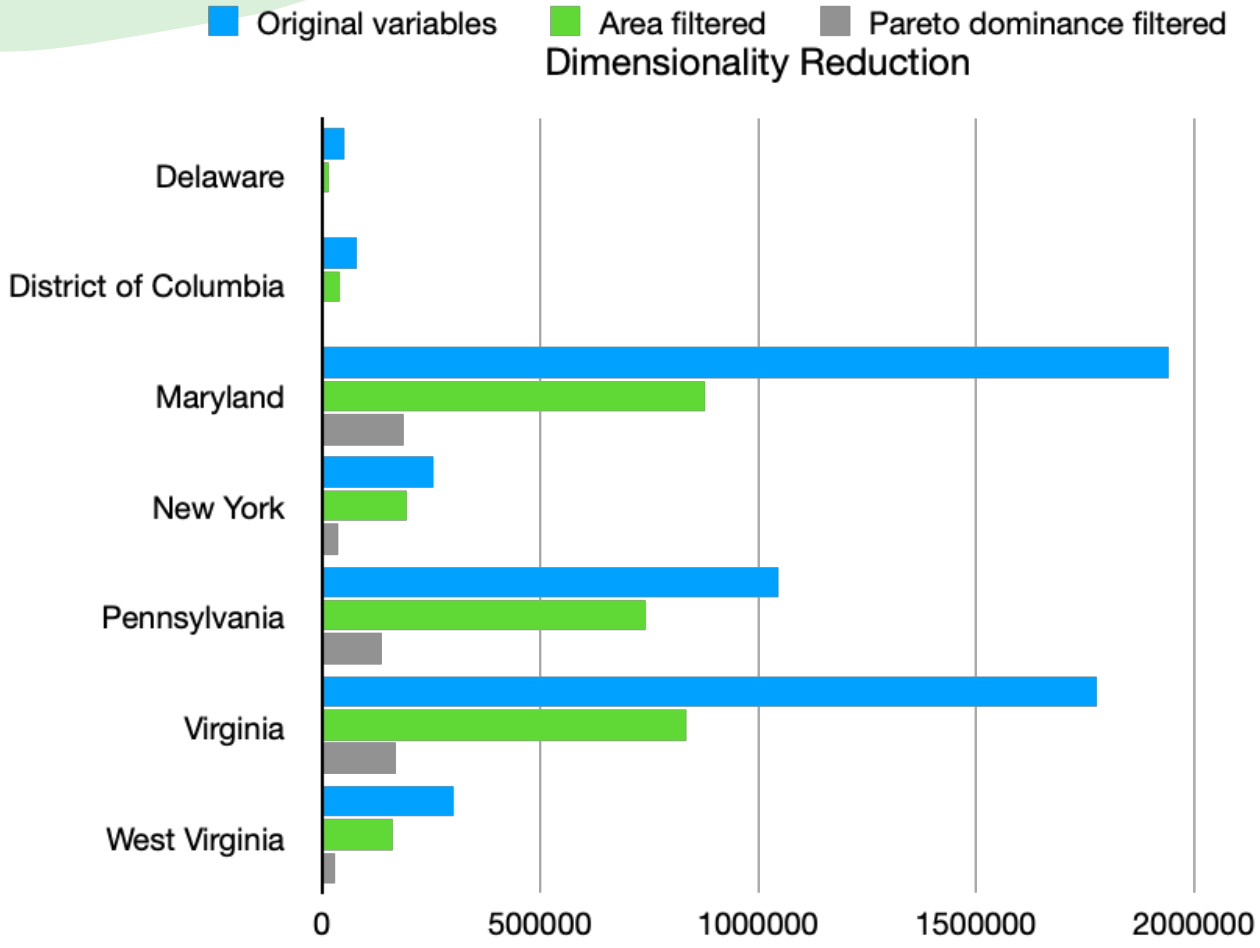
Example of reduction of dimensionality on Full Season Soybeans.

Cover Crop Traditional with Fall Nutrients Rye Early Drilled (Efficient Solution)

Cover Crop Traditional Rye Early Drilled (Efficient Solution)



Comparison in the number of variables



Reduction from
5,450,640 variables
to
565,853 variables
89%

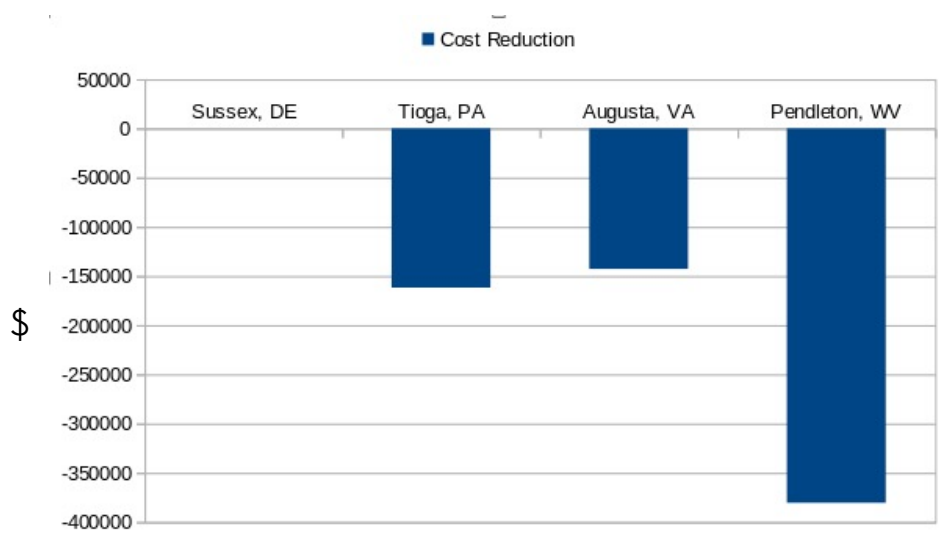
*1)Development of a simplified point-based structured single-objective optimization procedure (**OPT2**)*

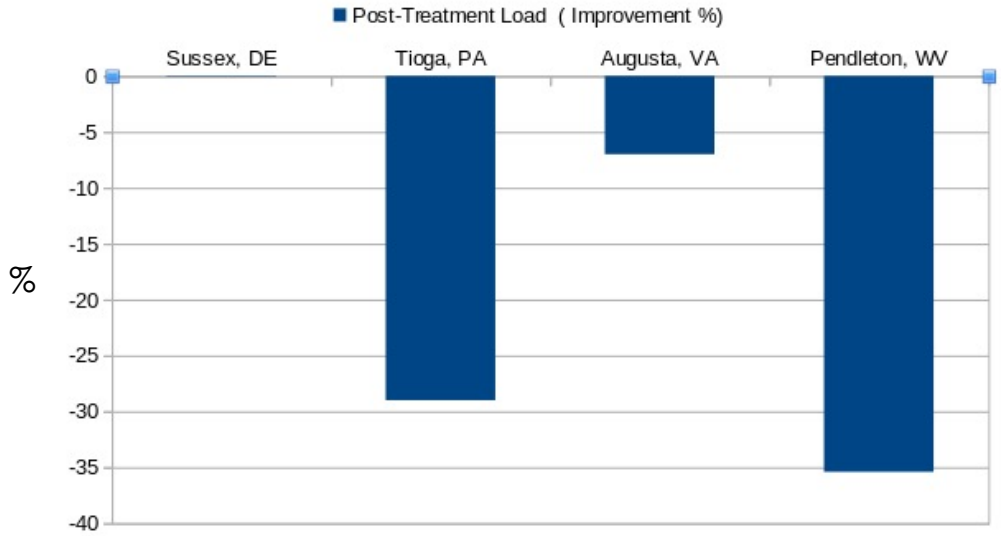
1) Improve the performance of the previous approach through customization.
2) As the problem at hand is a large-scale optimization problem, we developed a method to screen solutions (briefly presented previously).

OPT2: Performance Improvements

- Improve the quality of solutions in both cost function and the load constraints
- Improve the execution efficiency”
  - The number of evaluations required
  - The execution time
- Four improvements were implemented on Ipopt
  - Create an initial feasible solution
  - Use gradients
  - C++ implementation
  - Change of solver so it can work with a high number of constraints

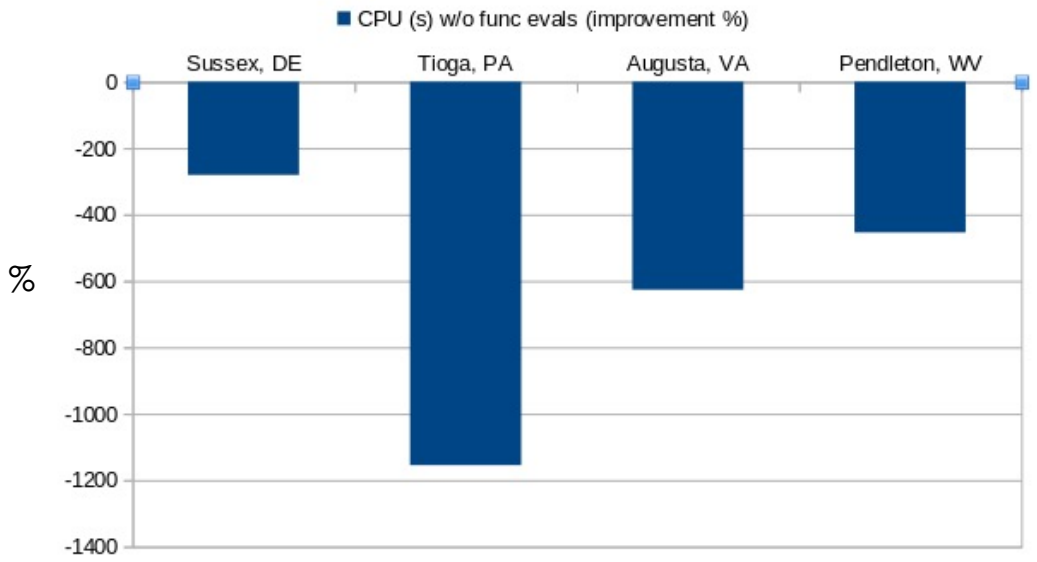
Result from several counties compared to original Ipopt (before reducing the dimensionality of the problem)

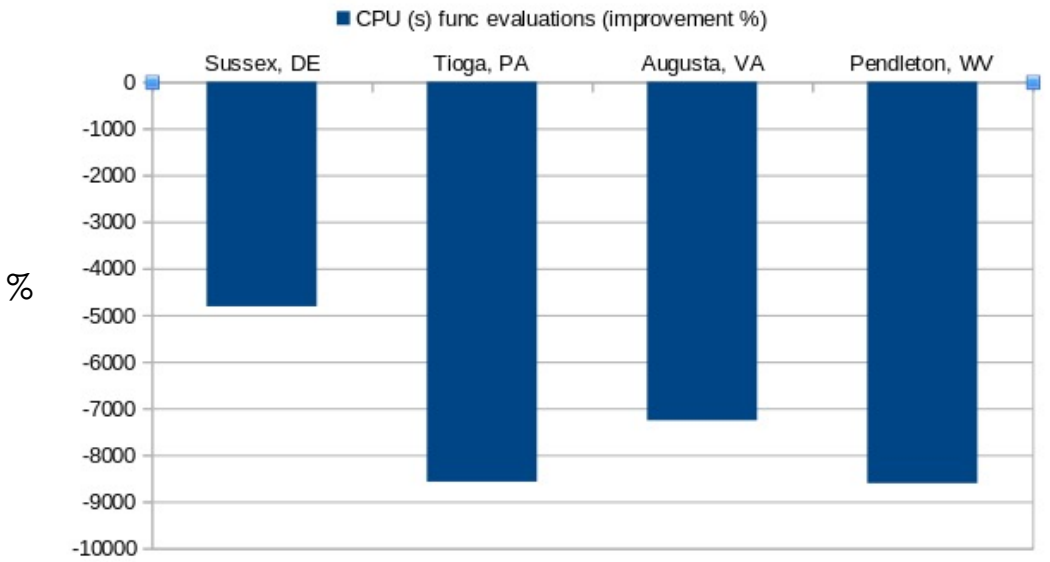




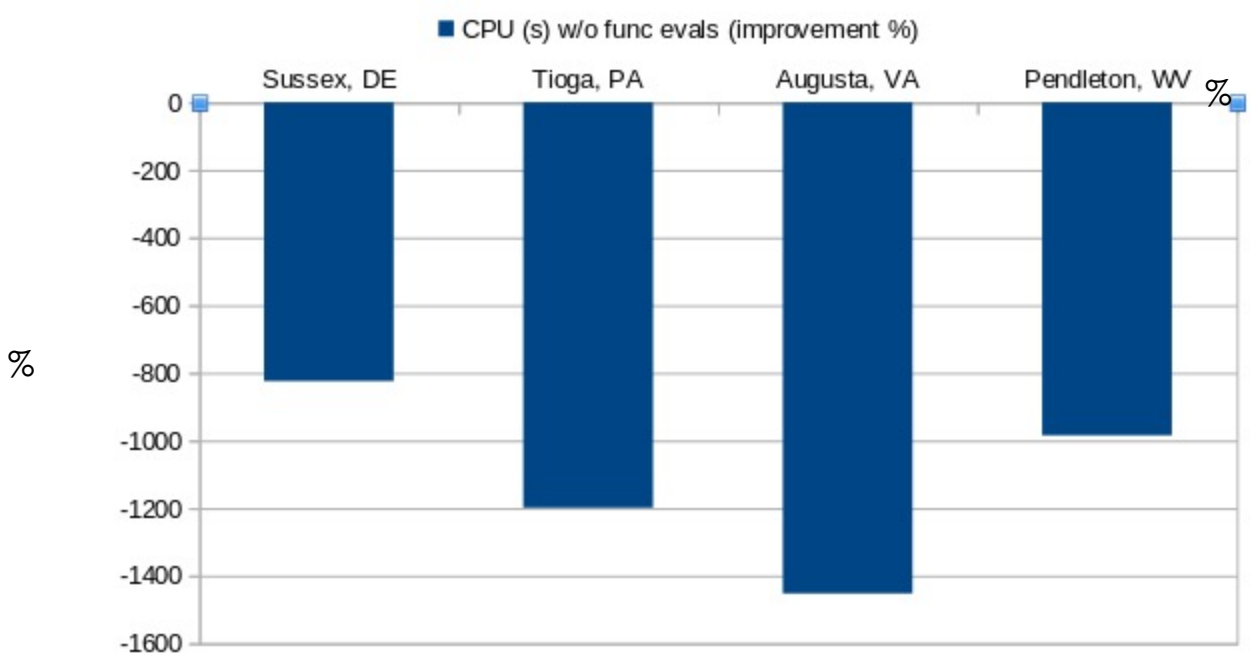
- Our new method reduced $137,377 on an average
- Our new method reduced 12% of the post-treatment load in average

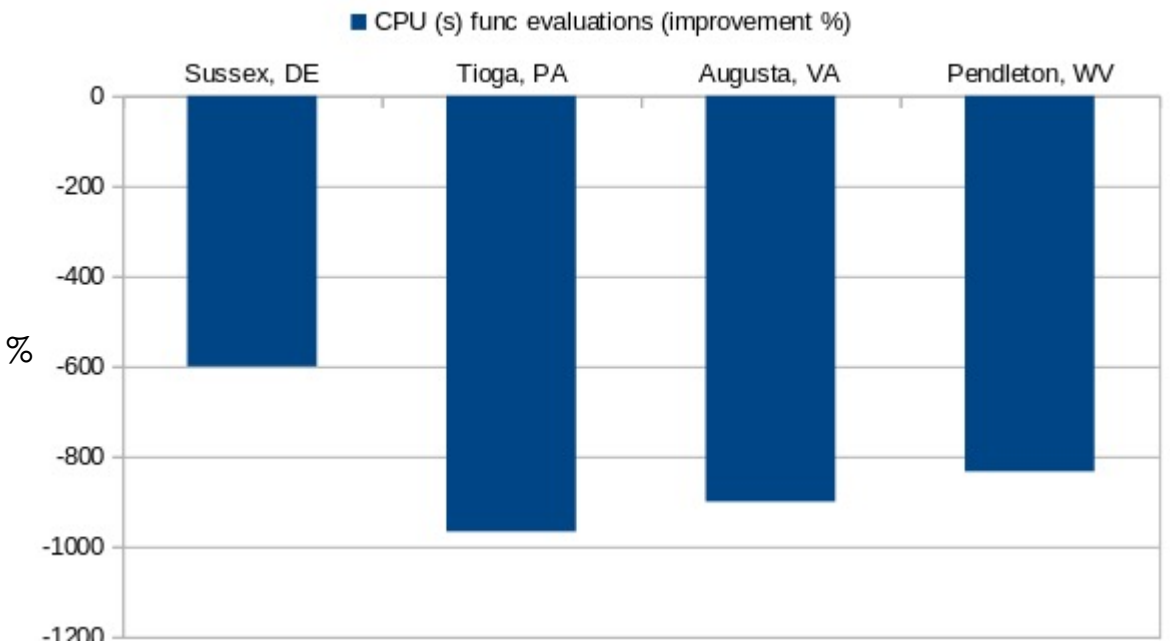
Speed Improvement compared to original Ipopt (before reducing the dimensionality of the problem)





The reduction in the number of variables impacts positively the execution time of our proposed approach.





*Development of a hybrid customized single-objective optimization procedure (**OPT3**)*
TASK FORCE

- **MSU Optimization team**: Kalyanmoy Deb, Nejadhashemi Amirpouyan, Gregorio Toscano, Sebastián Hernández, and Julian Blank
- **Data center**: Megan Thynge
- **Application development team**: Tim Paris, Rajendra Bojja, and Martin Koslof
- **Network team**: John Massey
- **CAST Expert**: Jessica Rigelman

Completed tasks under OPT3

1)We already have an initial GA that solves the mathematical problem and that will be our base algorithm.

2)Set up of a running environment machine (AWS S3, secure connection).

3) Produce the required files for configuring and running scenarios.

4) Capability to send scenarios and retrieve outputs.

Remaining tasks under OPT3

- Development of an API to execute automatically with the different scenarios (Application development team)
- Integration of the API with the performed algorithms.

CAST System and Optimization: Next Steps

- Finish the development of the hybrid customized single-objective optimization procedure (OPT3).
- Develop of a population-based single-objective optimization procedure (Opt4) using an evolutionary algorithm.