

Development of a Multi-Objective Optimization Tool for the Selection and Placement of BMPs for Pesticide (Atrazine) Control

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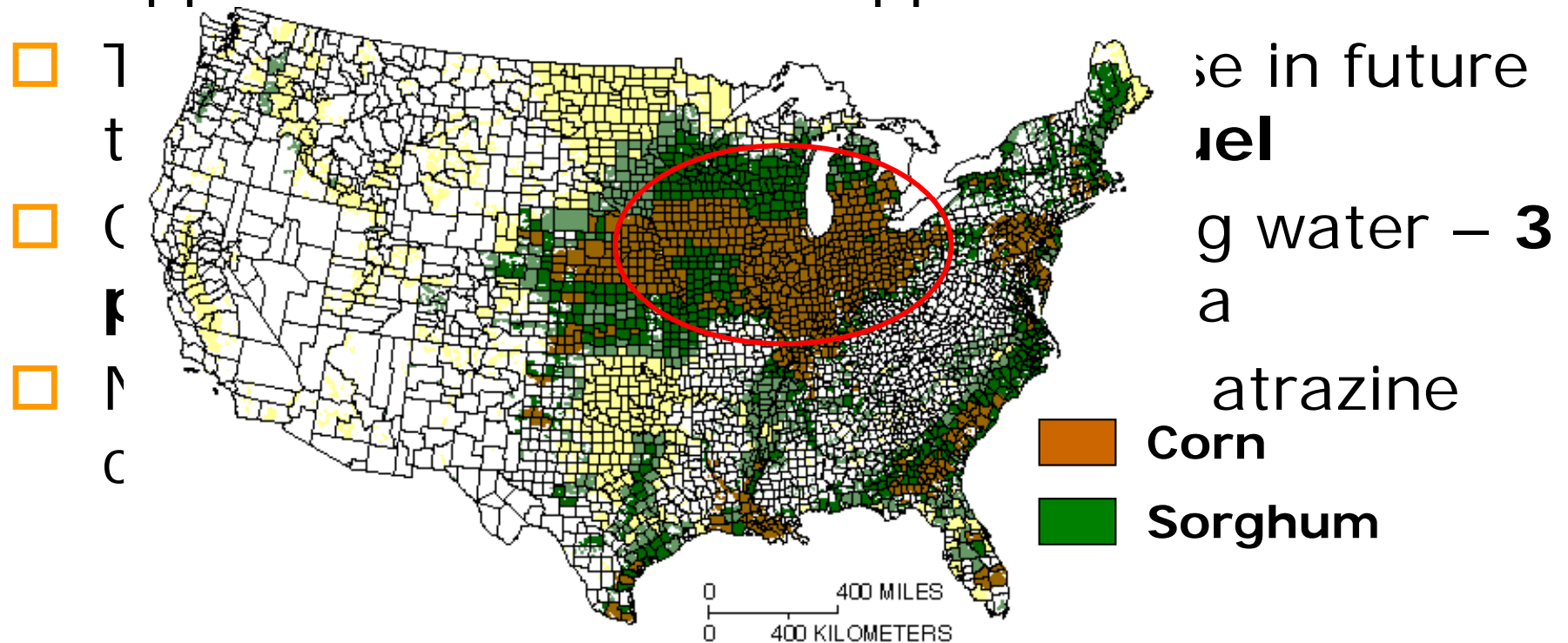
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Atrazine in the Midwest

- Application in US – **34,000 tons** in 2003
- Application rate– **85%** application in **corn**

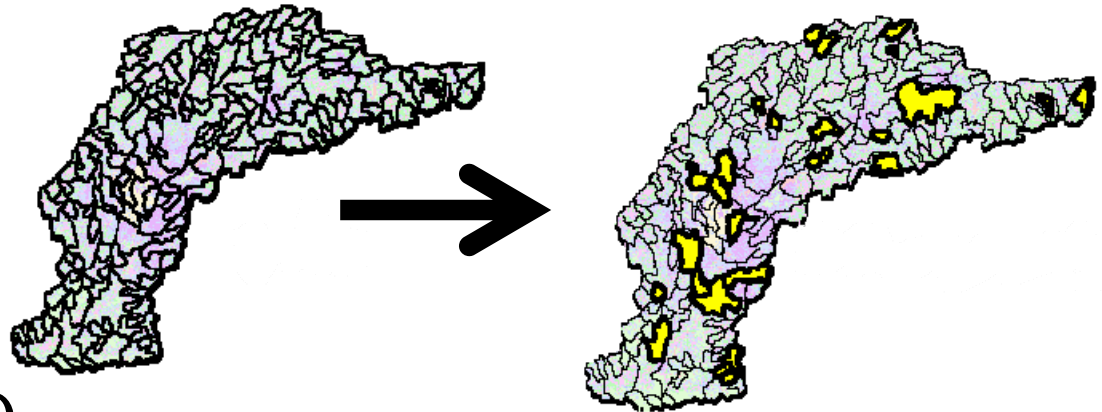


Objectives

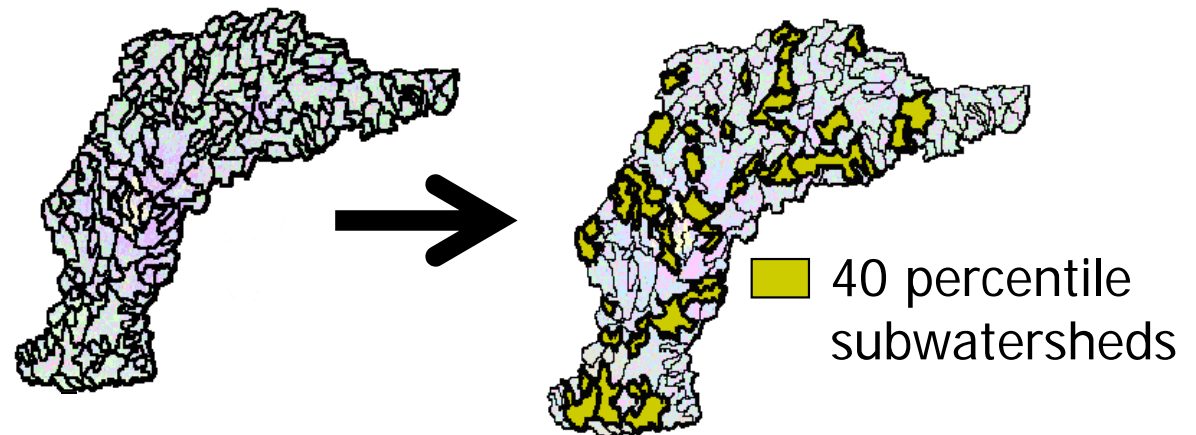
- Develop a multi-objective optimization model that optimizes BMP selection and placement in a watershed
 - Minimize atrazine loading for the watershed
 - Minimize the net-cost for BMP implementation in the watershed

Strategies used for BMP selection and placement

□ Random selection

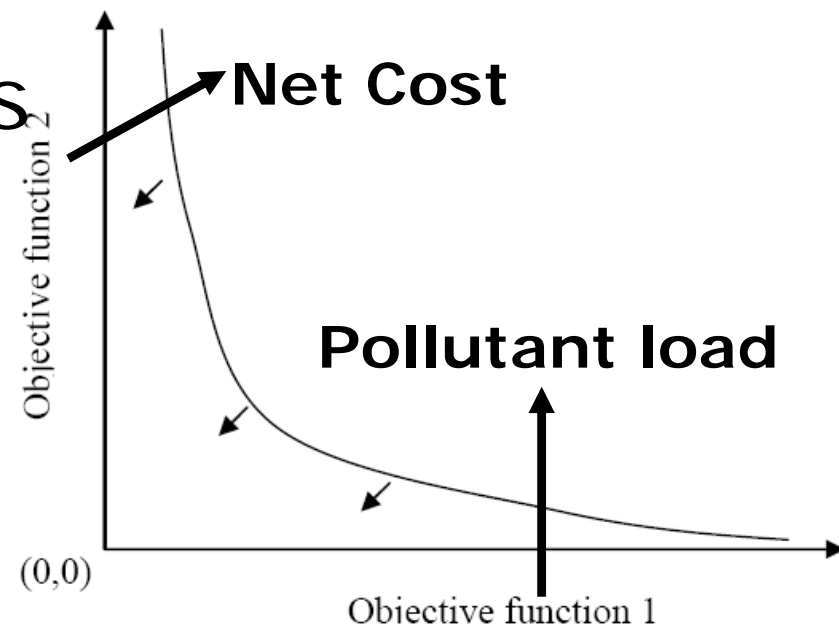


□ Targeting the BMPs




Optimization

- Global multi-objective optimization
 - Objective functions and constraints
 - Subjectivity
- Optimization algorithms
 - Genetic algorithms
 - Simulated annealing
 - Tabu search



Previous approaches to optimize BMP placement

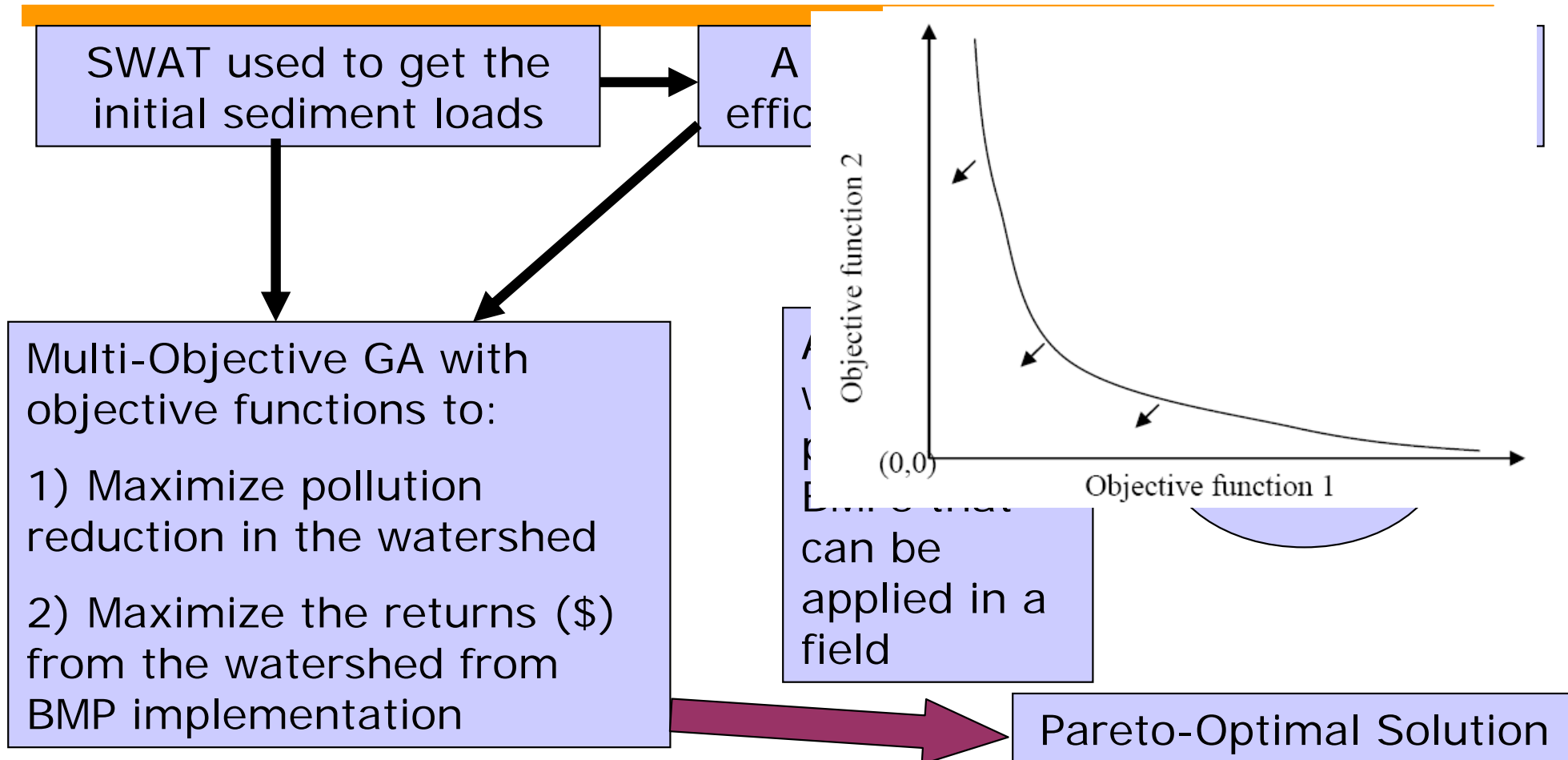
- **Genetic Algorithms (GAs)** in combination with a watershed model used to optimize BMPs¹
- **Simultaneous** single objective optimization 
- **Dynamic linkage** with the watershed model: limited application to small watersheds

¹Chatterjee, 1997; Srivastava et al., 2002; Veith et al., 2003; Gitau et al., 2004; Bekele et al., 2005; Arabi et al., 2006

Research focus

- **Multi-objective optimization** framework using Genetic Algorithm (GA) for atrazine reduction
- **BMP tool**: replaces the dynamic linkage during optimization
- BMP selection and placement on a **large watershed** (8 digit HUC watersheds)

Methodology: BMP optimization



Optimization: Objective function mathematic formulation

- Objective 1: Total Atrazine Reduction

$$\sum_{hru=1}^m \sum_{bmp=1}^n \text{Eff}_{bmp} \times \text{Atrazine}_{hru} \times \text{Area}_{hru}$$

- Objective 2: Total Cost

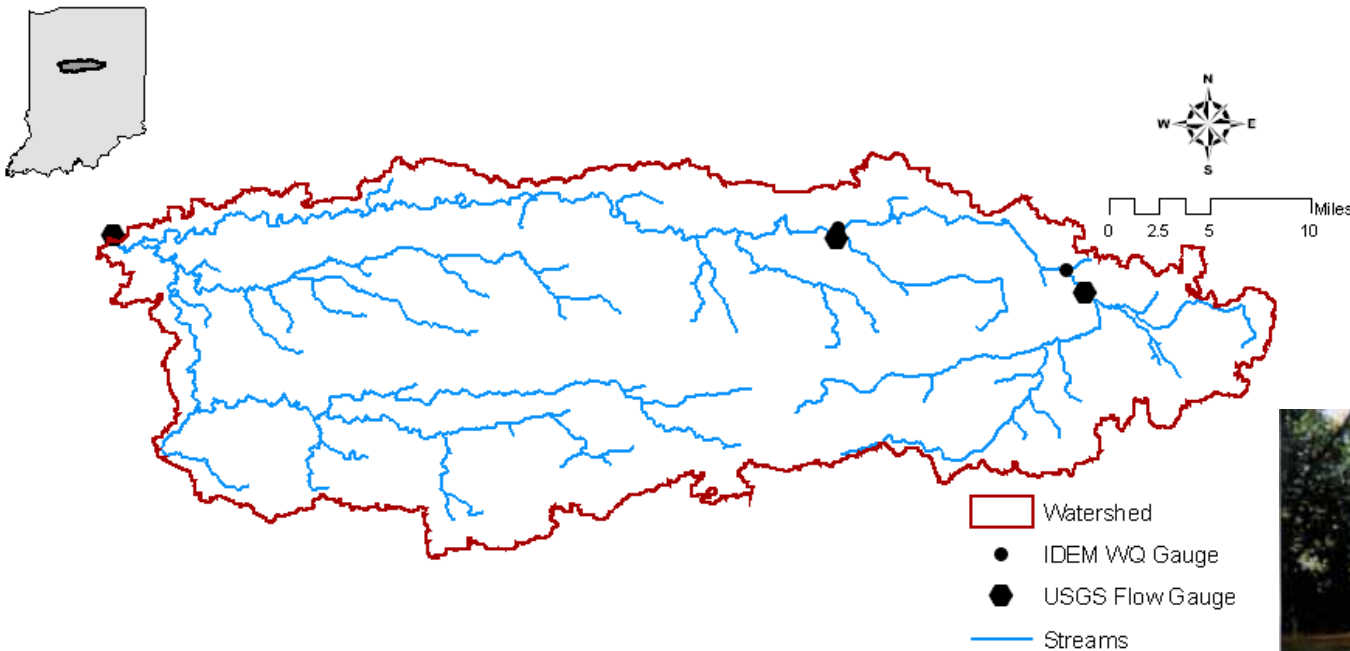
$$\sum_{hru=1}^m \sum_{bmp=1}^n \text{Cost}_{bmp} \times \text{Area}_{hru}$$

■ Cost_{bmp} includes BMP placement, and maintenance costs

Wildcat Creek Watershed, IN

- Northcentral Indiana
- Drainage area of 1956 km²
- Corn: 41%, Soybean: 41%

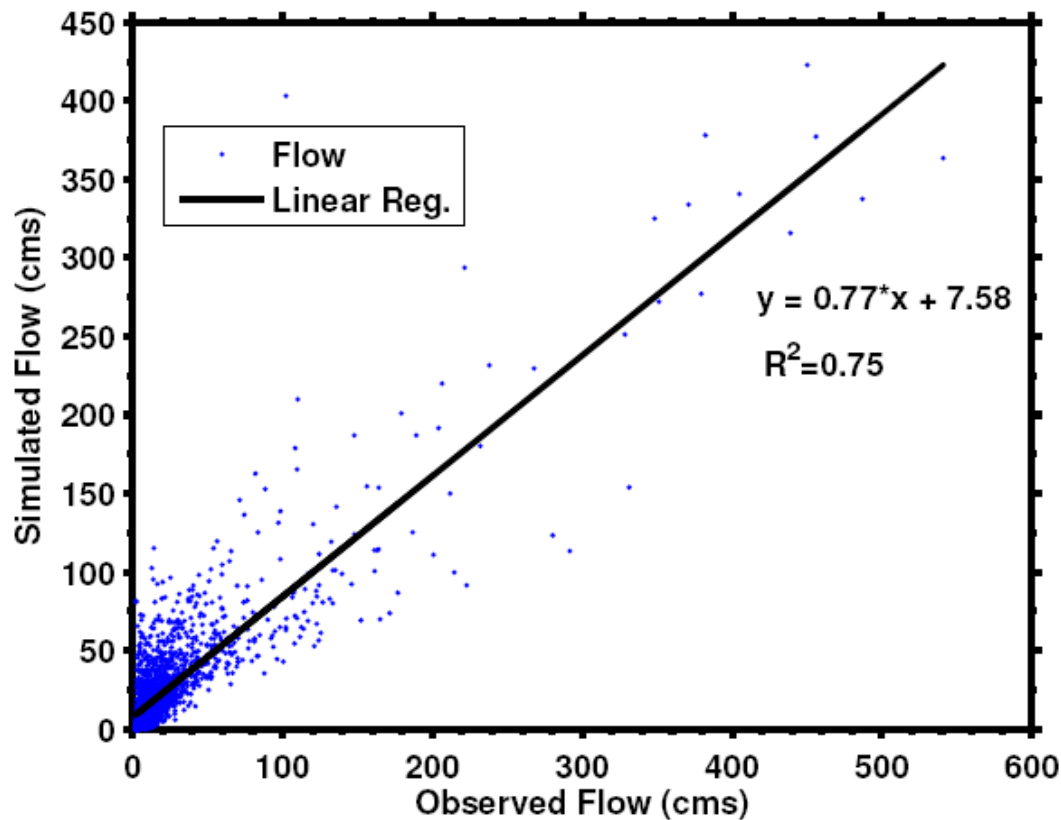
Pesticide (atrazine)



SWAT to simulate atrazine in the watershed

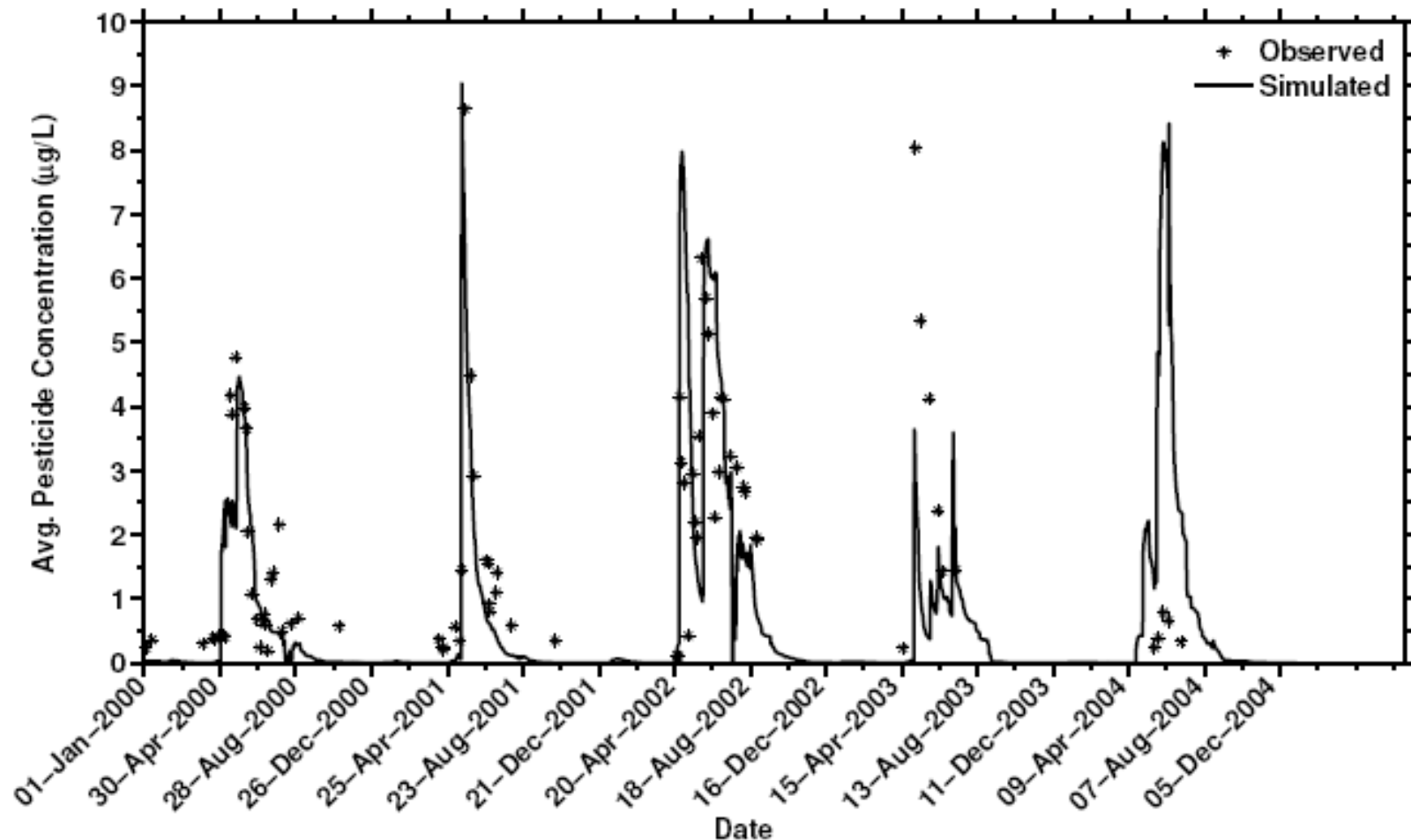
- Soil and Water Assessment Tool (SWAT) to simulate stream flow and atrazine
 - GLEAMS algorithms to simulate one pesticide at a time
 - Routing and degradation

SWAT Calibration for flow



- Calibration performed at 3 USGS gage locations in the watershed

SWAT calibration for pesticide



Allele set & BMP tool

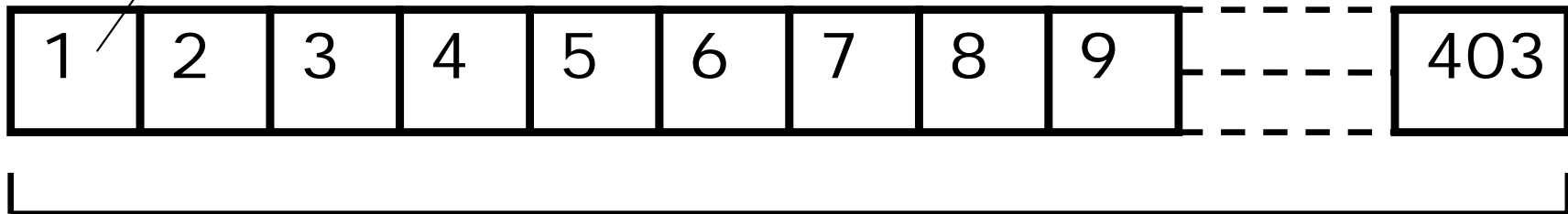
Crop	Allele set
Corn	Buffer strip: 0, 20, 27, 30m
	Conventional, and No-till
Soybean	'Null'
Forest	'Null'
Pasture	'Null'

- 8 BMP placement scenarios **simulated in SWAT** to develop the BMP tool
- Economic information obtained from Indiana EQIP

GA Chromosome string

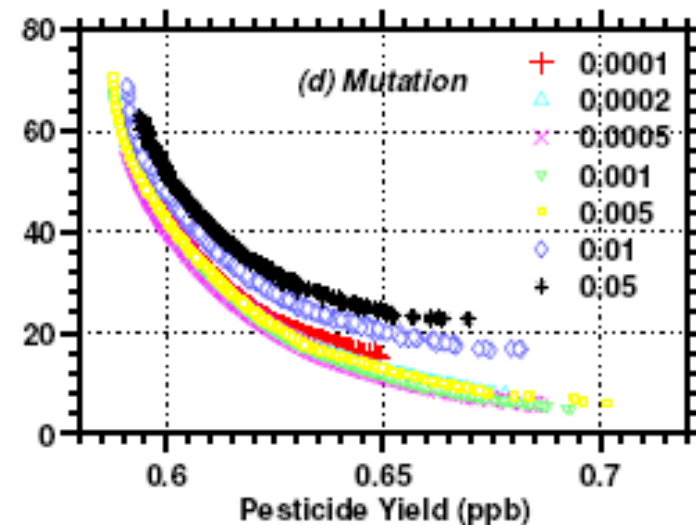
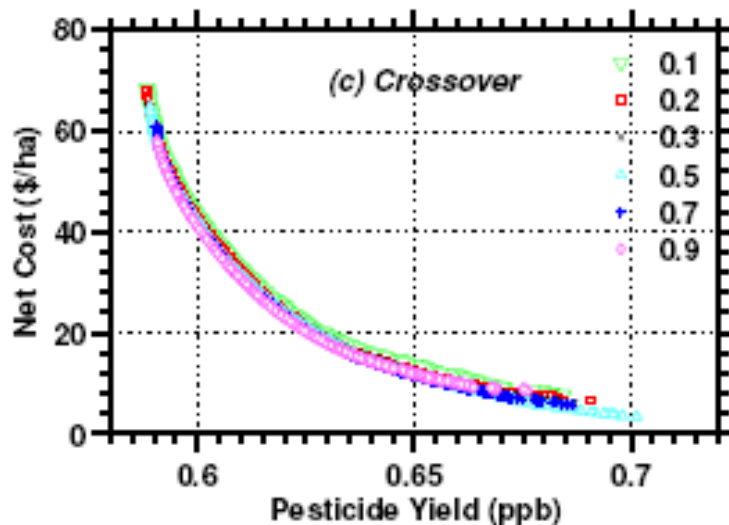
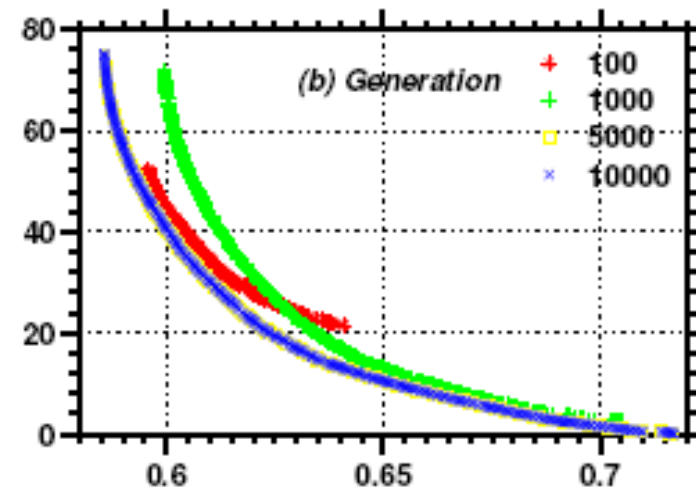
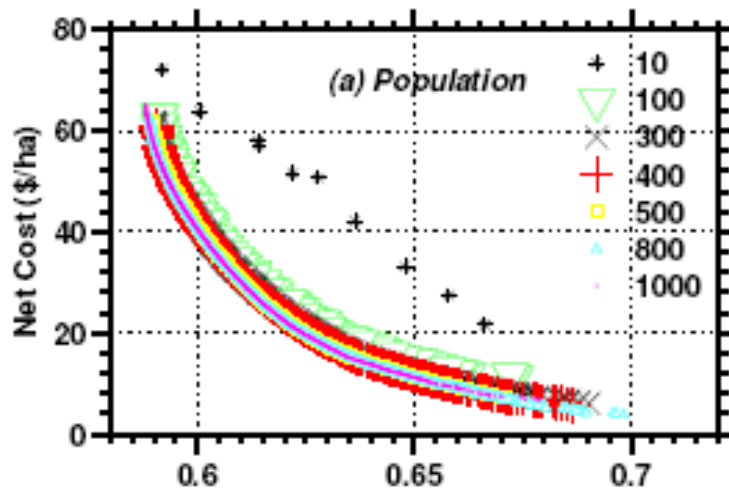
BMP Representation

BMP :: f(HRU, LUSE)



Chromosome
(Size: No. of HRUs)

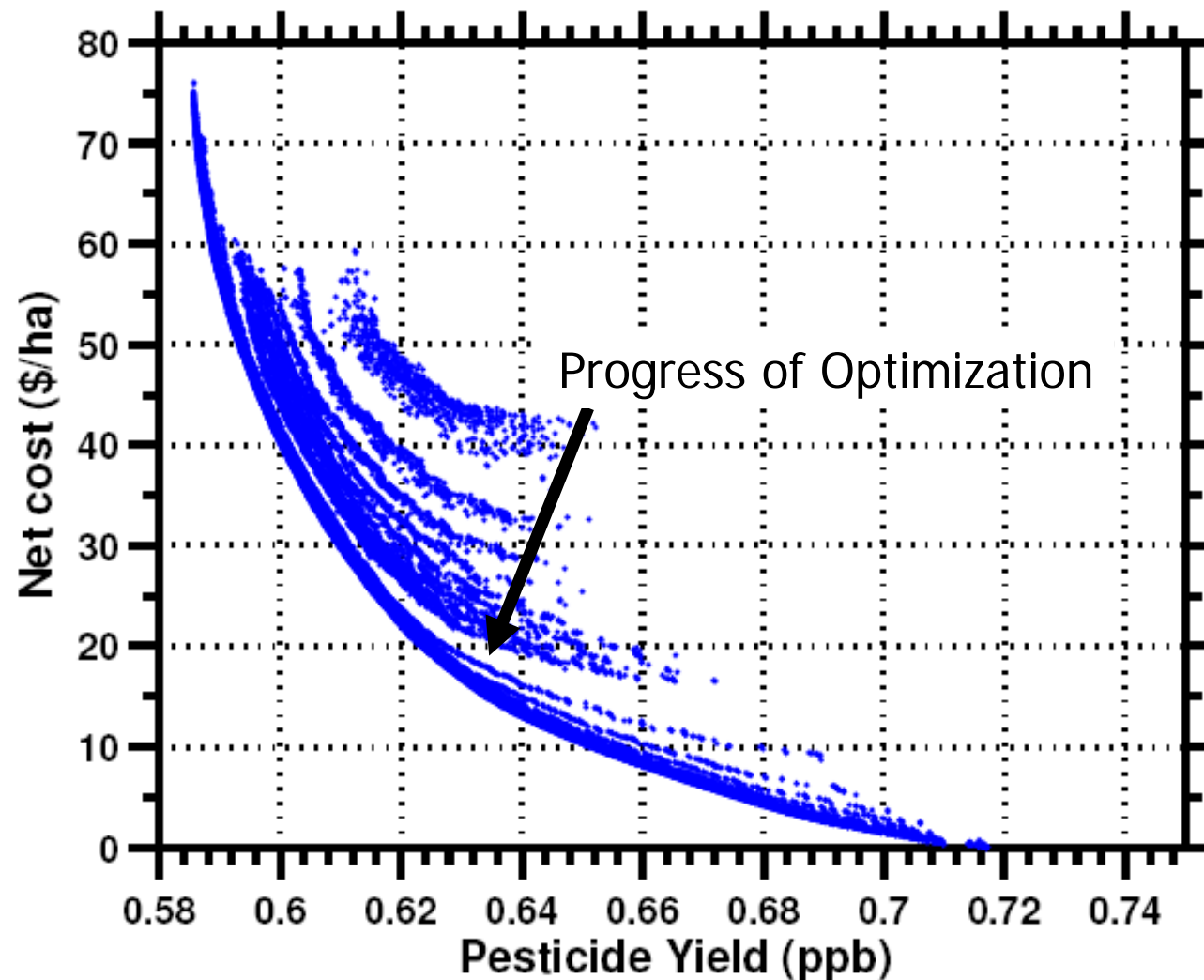
Sensitivity analysis and estimation of GA parameters



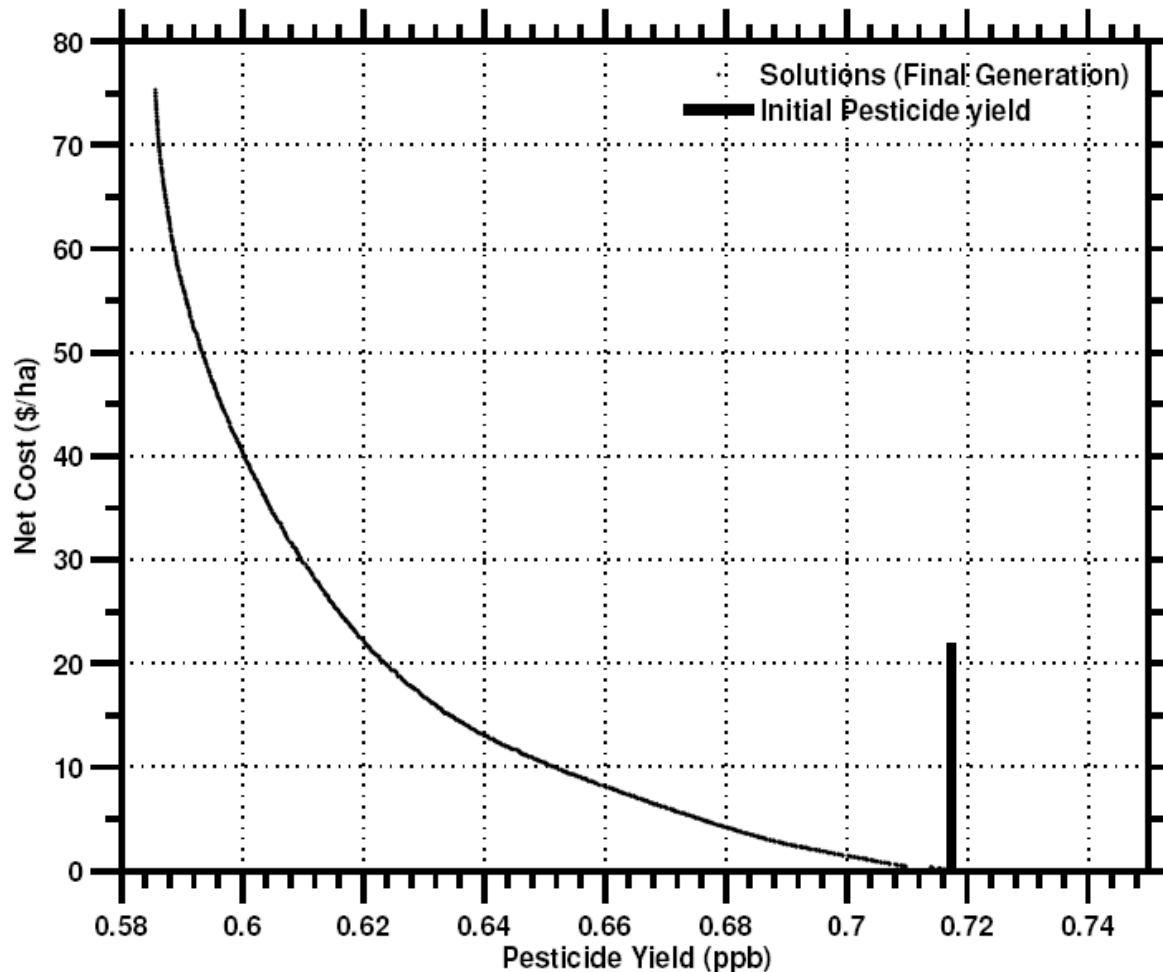
GA parameters used for optimization

- Population = 800
 - No. of generations = 5,000
 - Crossover probability = 0.5
 - Mutation probability = 0.001
-
- 1 hour on an CentrinoDuo@2.16GHz

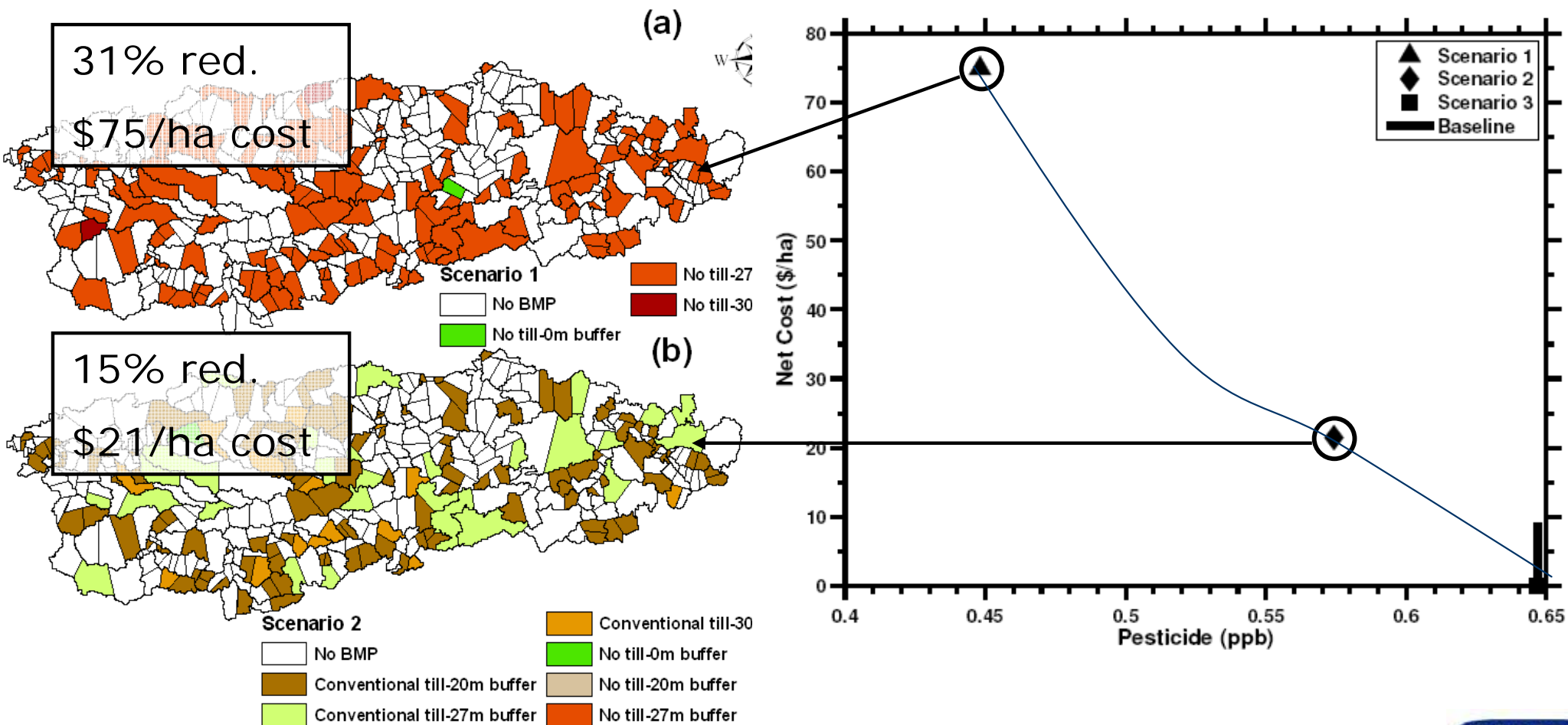
Progress of pareto-optimal front for pesticide model



Pareto-optimal front after the final generation



SWAT simulated atrazine yields at outlet of subbasin 9



Results

- \$0-\$75/ha/yr
 - 0-18.5% reduction in atrazine concentration at a HRU level
 - 0-31% reduction in atrazine concentration obtained using routing model (SWAT)
- Range of solutions – near optimal pollution reduction for the available costs

Conclusions

- ❑ Multi-objective BMP selection and placement tool applied for atrazine control
- ❑ BMP tool replace the dynamic linkage
 - Model applied on a large (8 digit HUC) watershed
- ❑ Model easily extendable to any watershed to address any water quality parameter of concern

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