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

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ASABE AIM 2008

June 30th 2008

Outline

- BMP placement for atrazine control
- Strategies used to select and place BMPs in a watershed
- Methodology: multi-objective optimization
- Results and discussion
- Conclusions

Pesticide (atrazine) in the Midwest

- Application in US – **34,000 tons** in 2003
- Application rate– **85%** application in **corn**[1]
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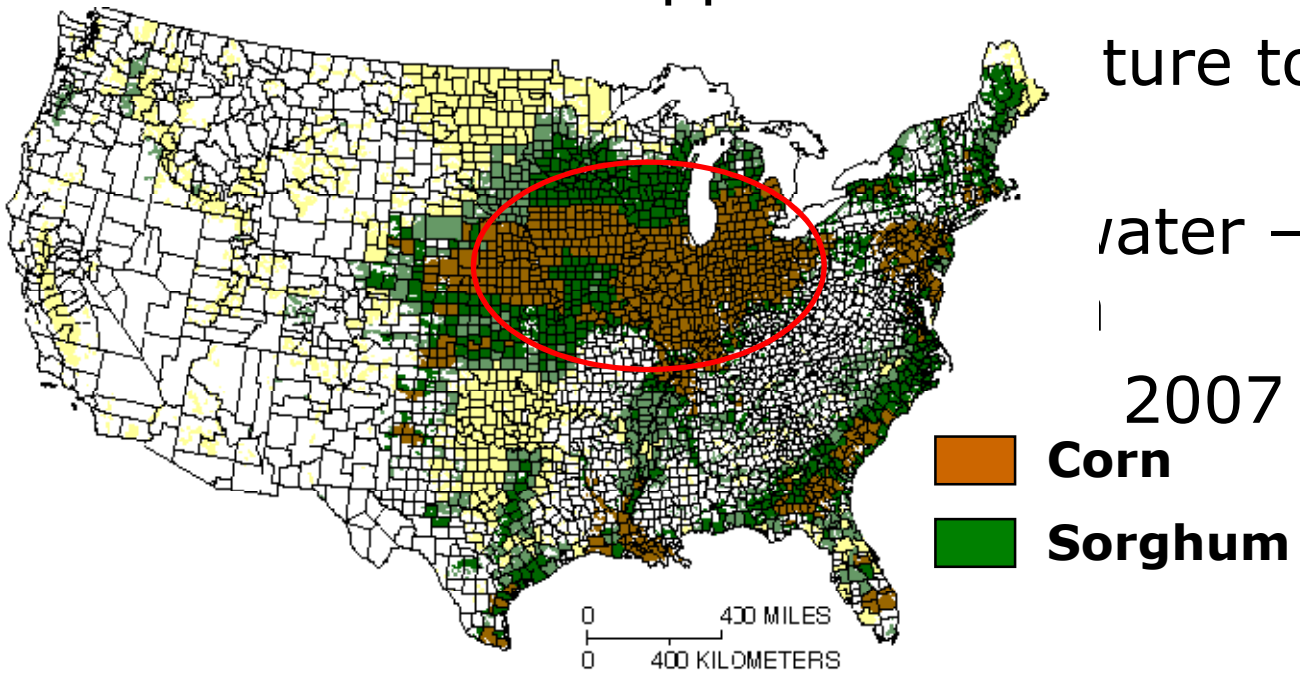
- **$7.**… 2007 for NPS…



[1]**Farm bill: An antidode for atrazine (NRDC)**

Objectives

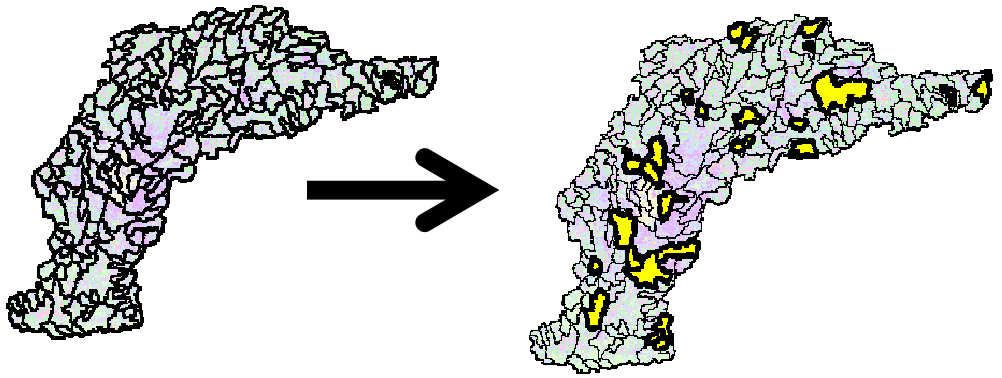
- Develop a multi-objective optimization model that optimizes BMP selection and placement in a watershed
  - Minimize atrazine loading for the watershed
  - Minimize the net-cost for BMP implementation in the watershed

BMPs to control atrazine

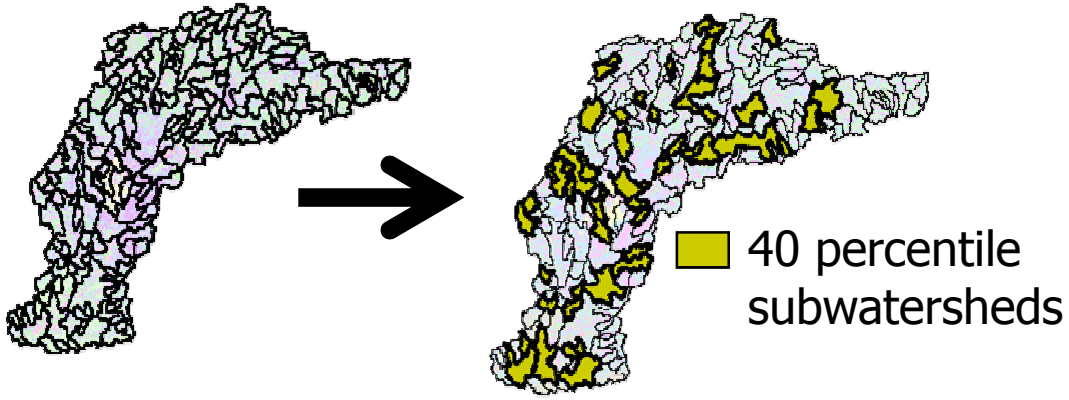
- Field buffer strips
- Tillage practices
- Atrazine incorporation
- Application rate and timing

Strategies used for BMP selection and placement

- Strategy 1: Random selection

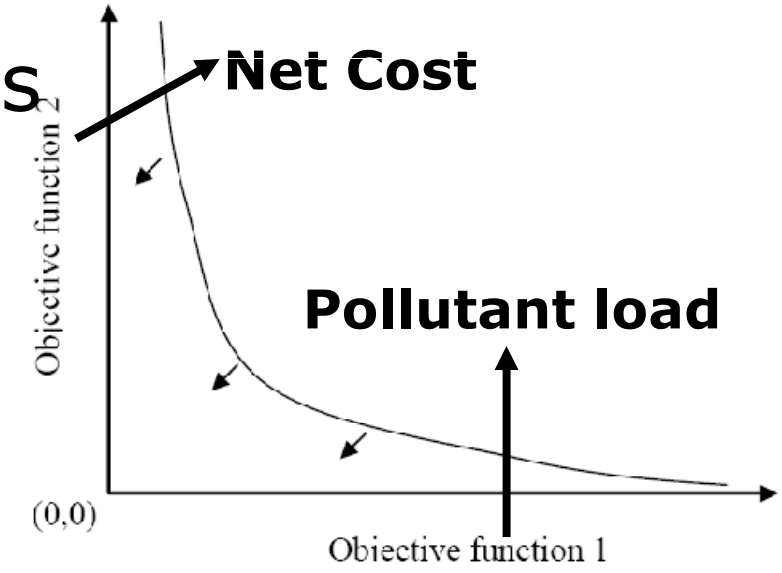


- Strategy 2: Targeting the BMPs



Strategy 3: Optimization

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



Literature Review

- **Genetic Algorithms** (GAs) in combination with a watershed model used to optimize BMPs[1]
- **Simultaneous** single objective optimization
- **Dynamic linkage** with the watershed model: limited application to small watersheds

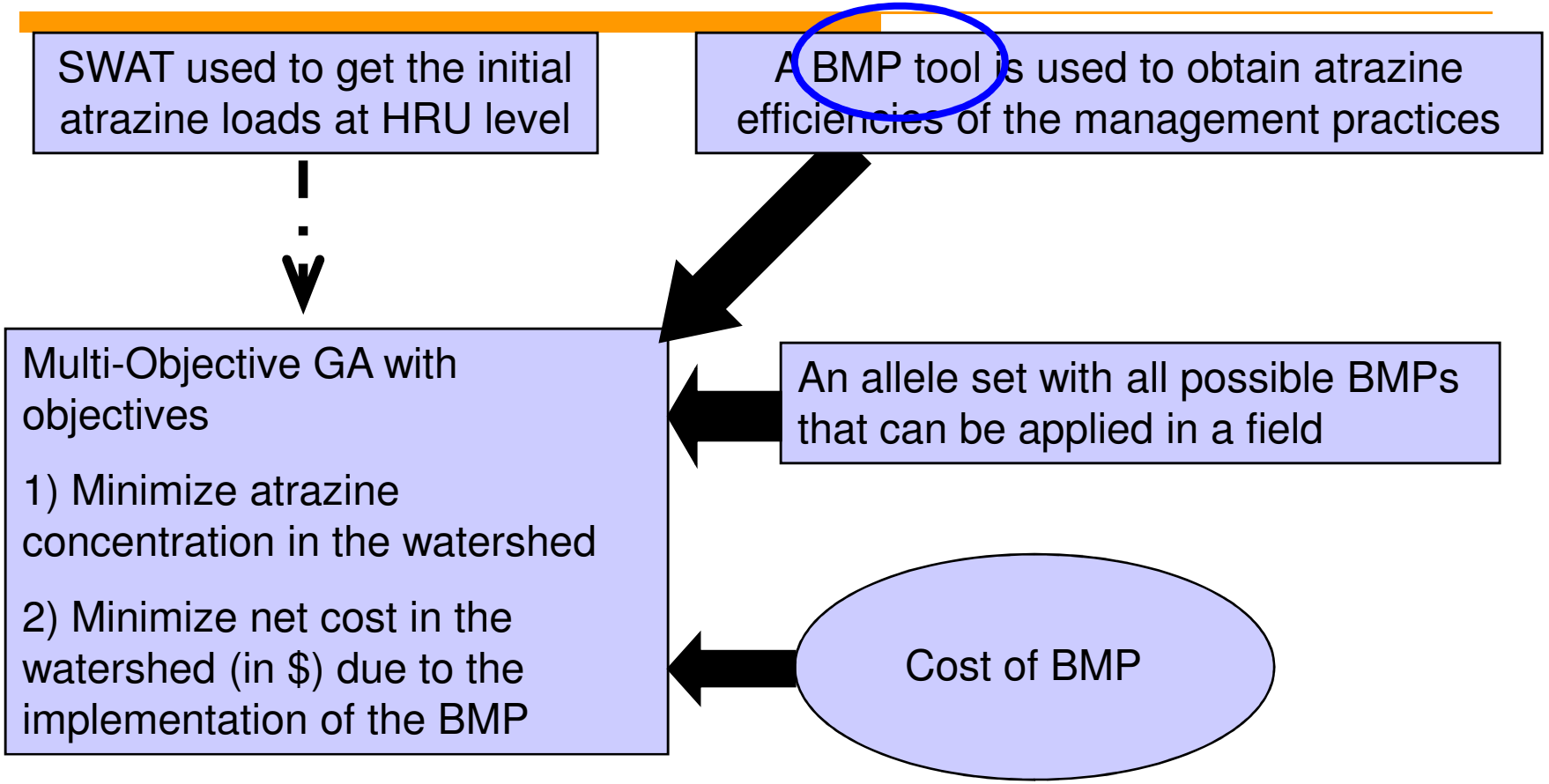
Bekele et al., 2005

[1]**Chatterjee, 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



Optimization: Objective function mathematic formulation

- Objective 1: Total Atrazine Reduction

$$\sum_{hru=1}^{m} \sum_{bmp=1}^{n} Eff_{bmp} \times Atrazine_{hru} \times Area_{hru}$$

- Objective 2: Total Cost Increase

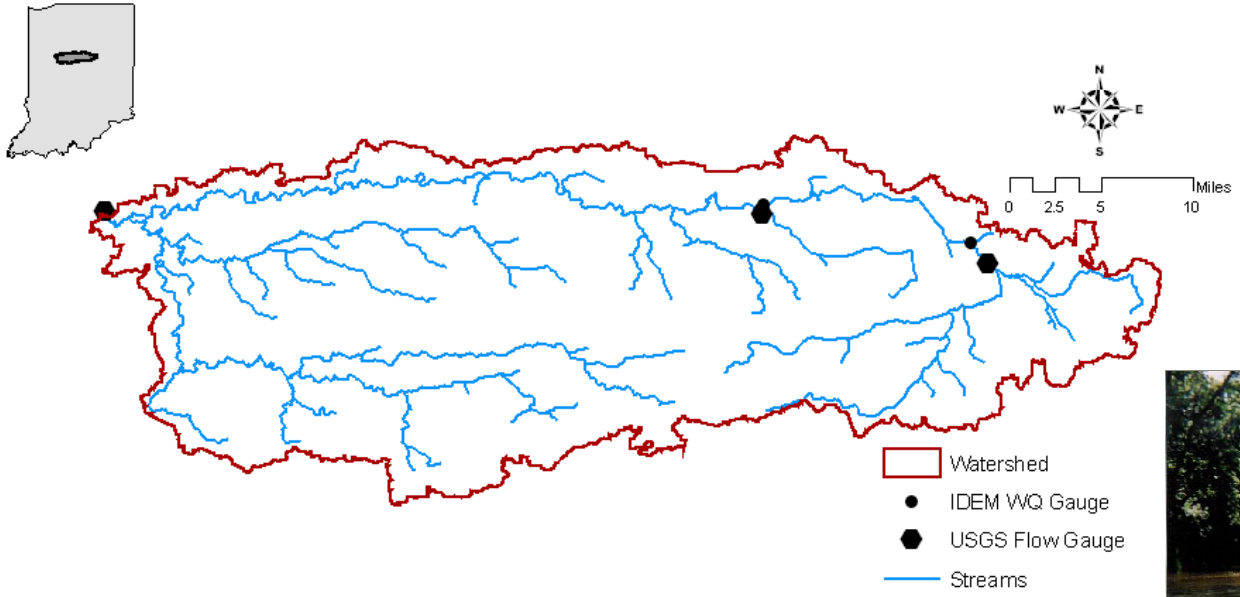
$$\sum_{hru=1}^{m} \sum_{bmp=1}^{n} Cost_{bmp} \times Area_{hru}$$

  - $Cost_{bmp}$ includes BMP placement, and maintenance costs

Wildcat Creek Watershed, IN

- Northcentral Indiana
- Drainage area of 1956 km^2
- Corn: 41%,Soybean: 41%

Pesticide (atrazine)



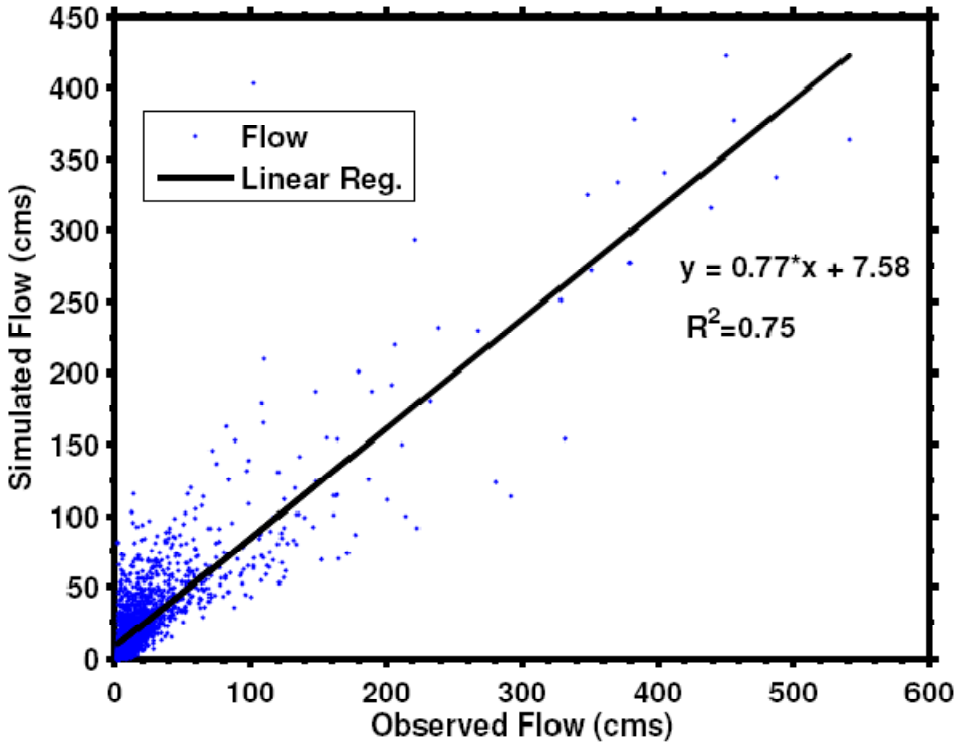
SWAT to simulate atrazine in the watershed

- 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 model

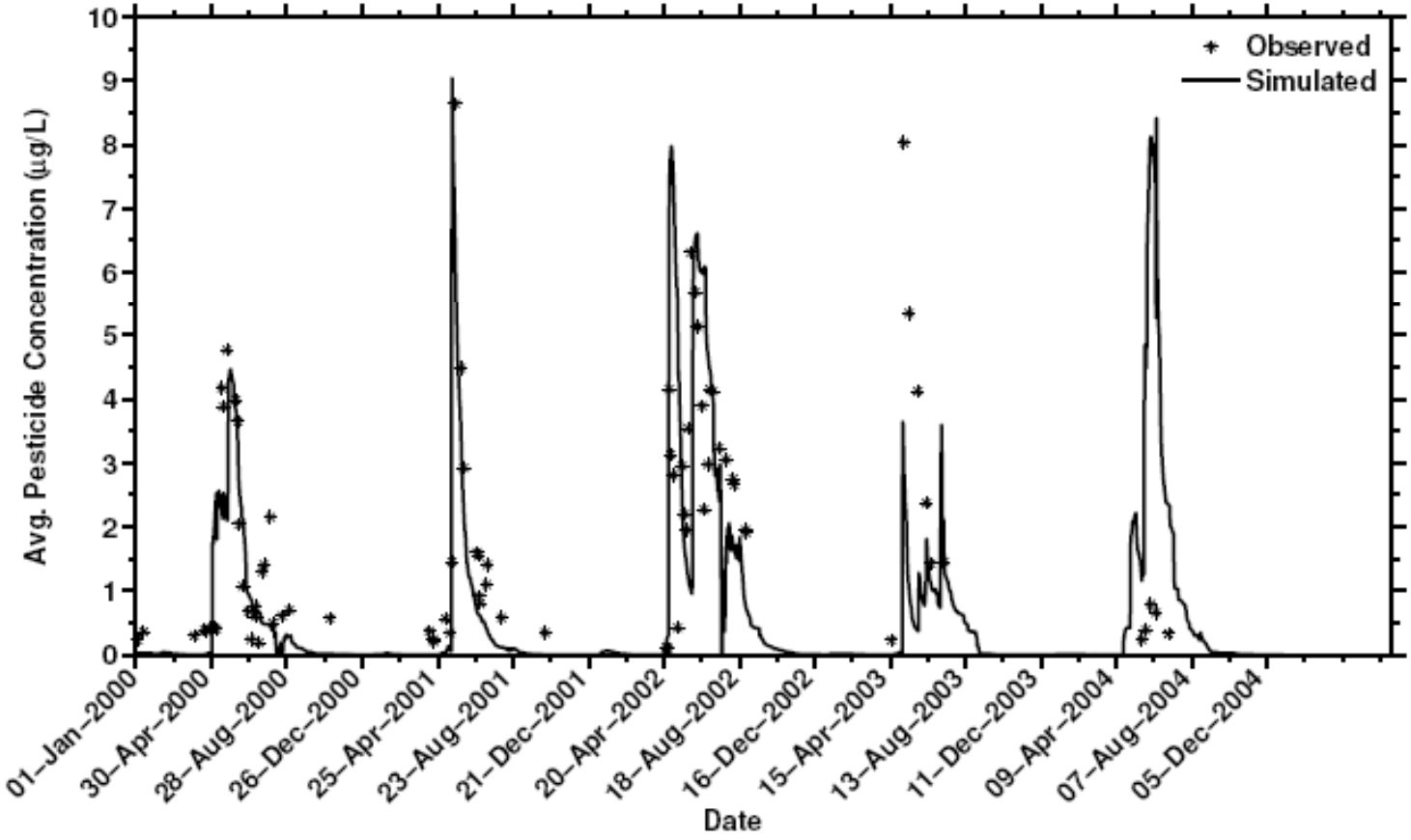
- Delineate the watershed into 109 subbasins and 403 HRUs
- Calibrated for flow and atrazine
- Simulate atrazine in soluble and adsorbed forms using linear isotherm

SWAT Calibration for flow



- Calibration performed at 3 USGS gage locations in the watershed

SWAT calibration for pesticide



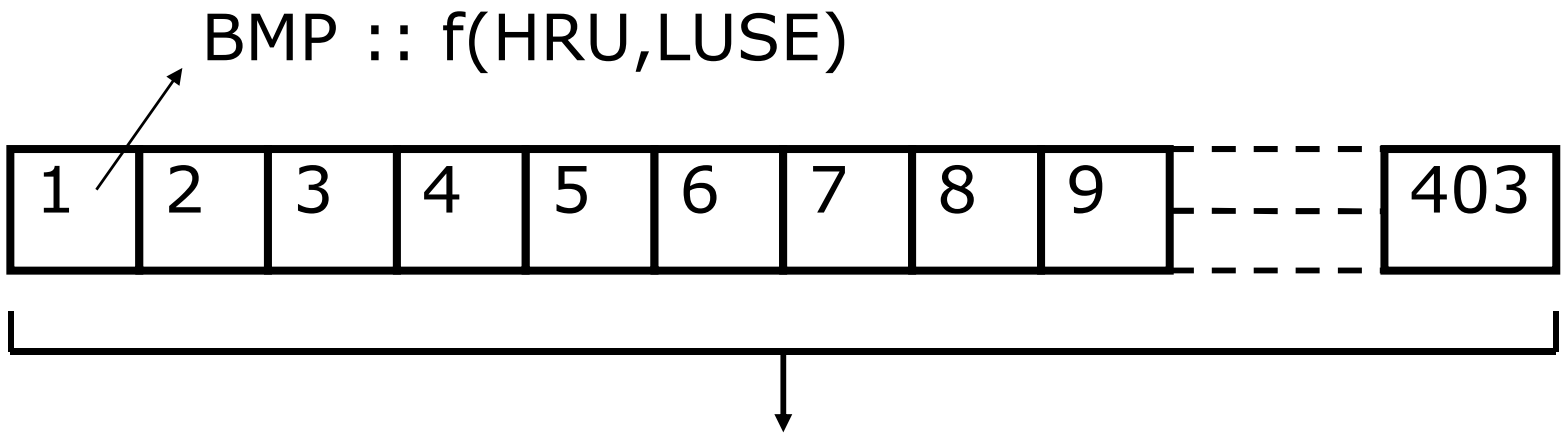
Allele set & BMP tool

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

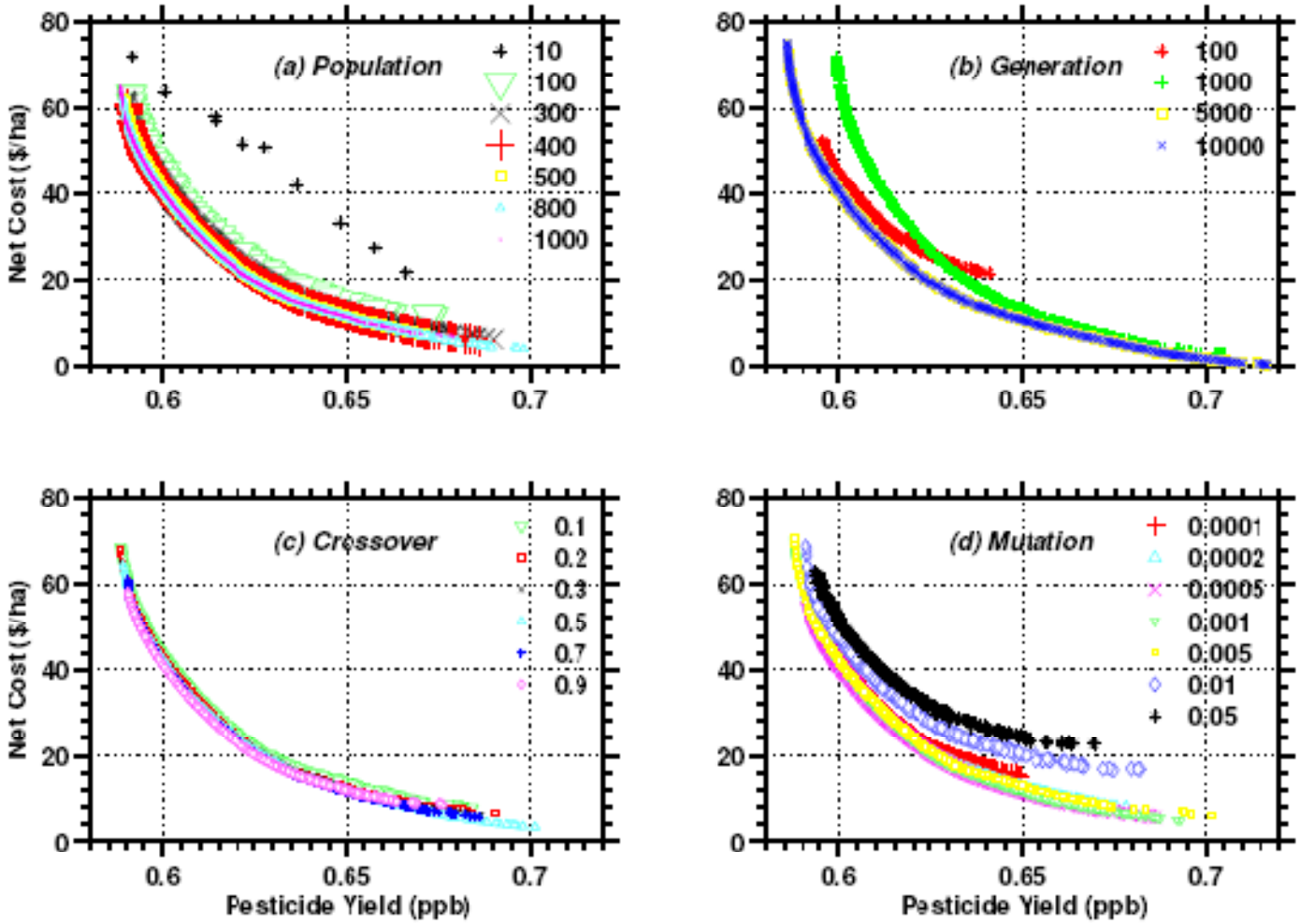
- 8 BMP placement scenarios **simulated in SWAT** to develop the BMP tool
- Economic information obtained from Indiana EQIP

GA Chromosome string

BMP Representation



Sensitivity analysis and estimation of GA parameters

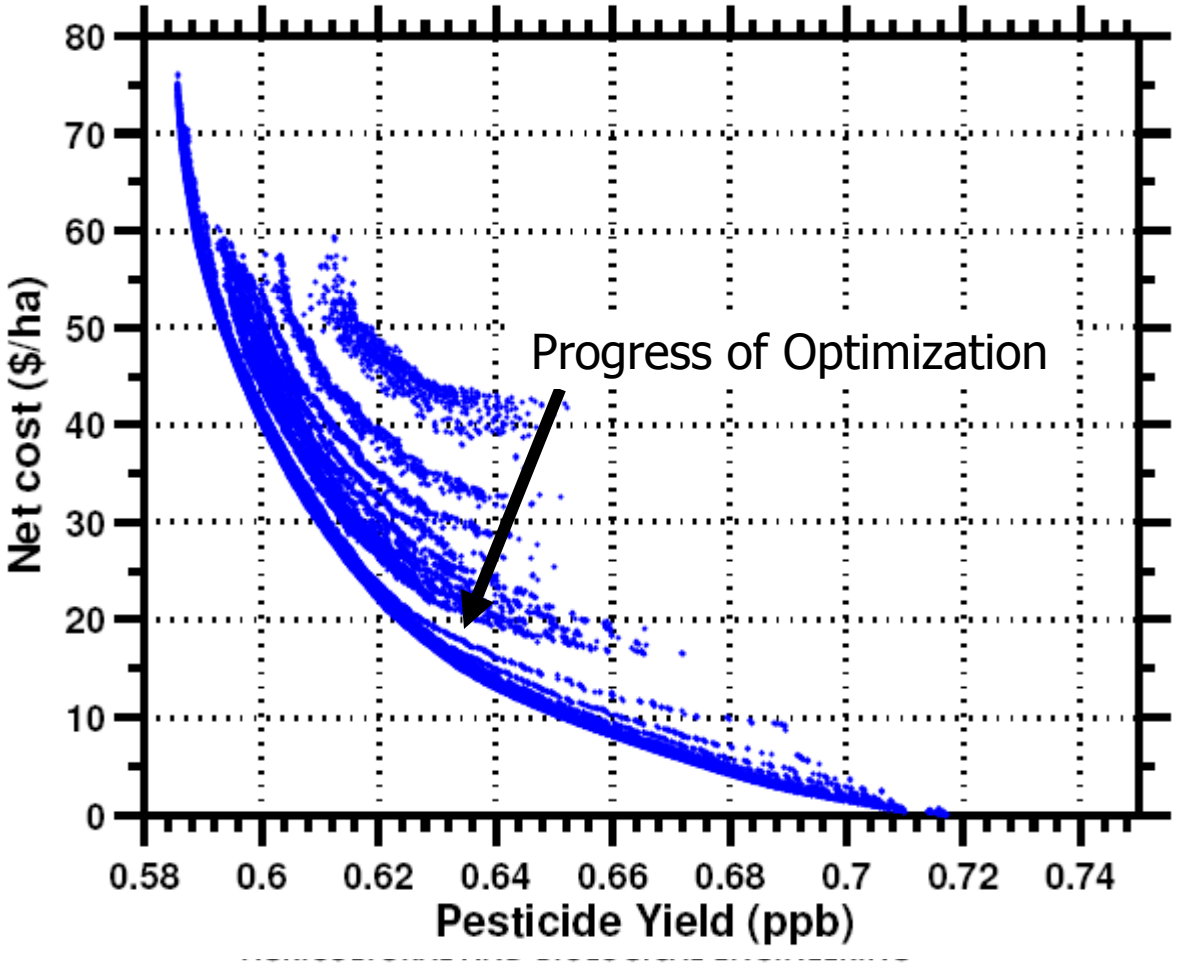


GA parameters used for optimization

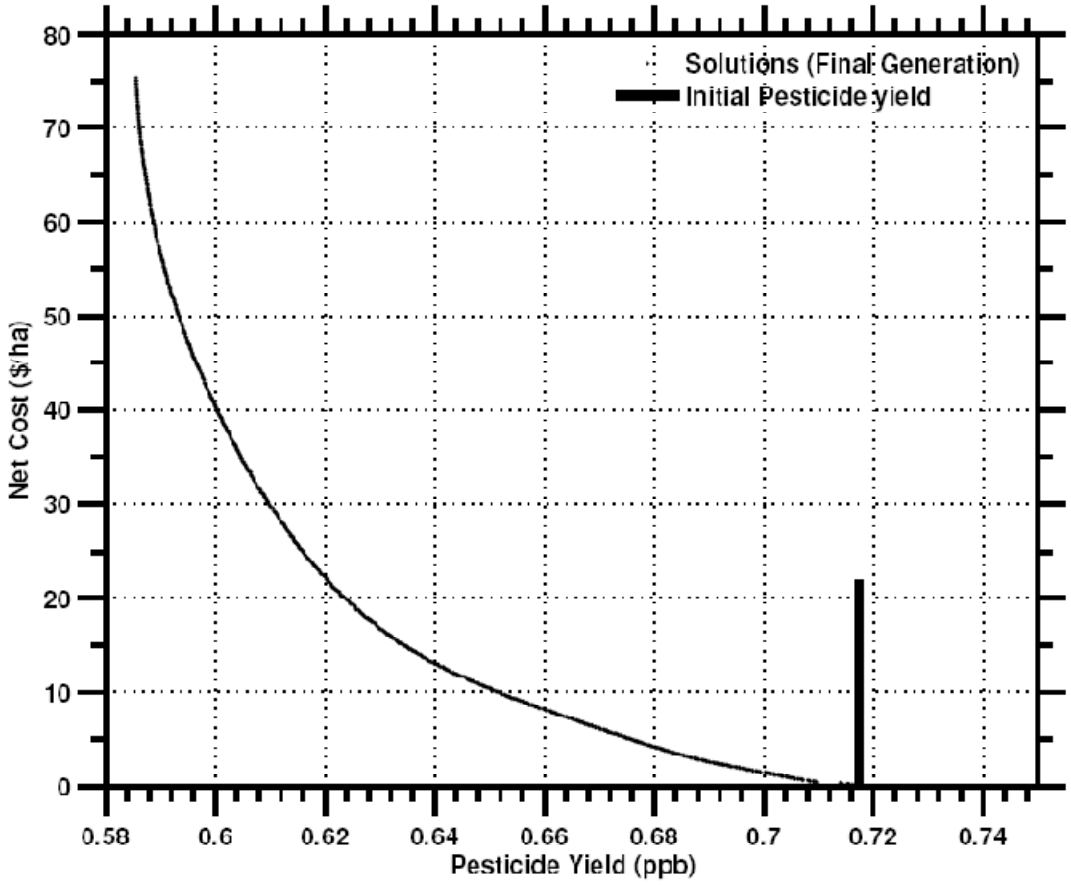
- Population = 800
- No. of generations = 5,000
- Crossover probability = 0.5
- Mutation probability = 0.001

  - 1 hour on an CentrinoDuo@2.16GHz

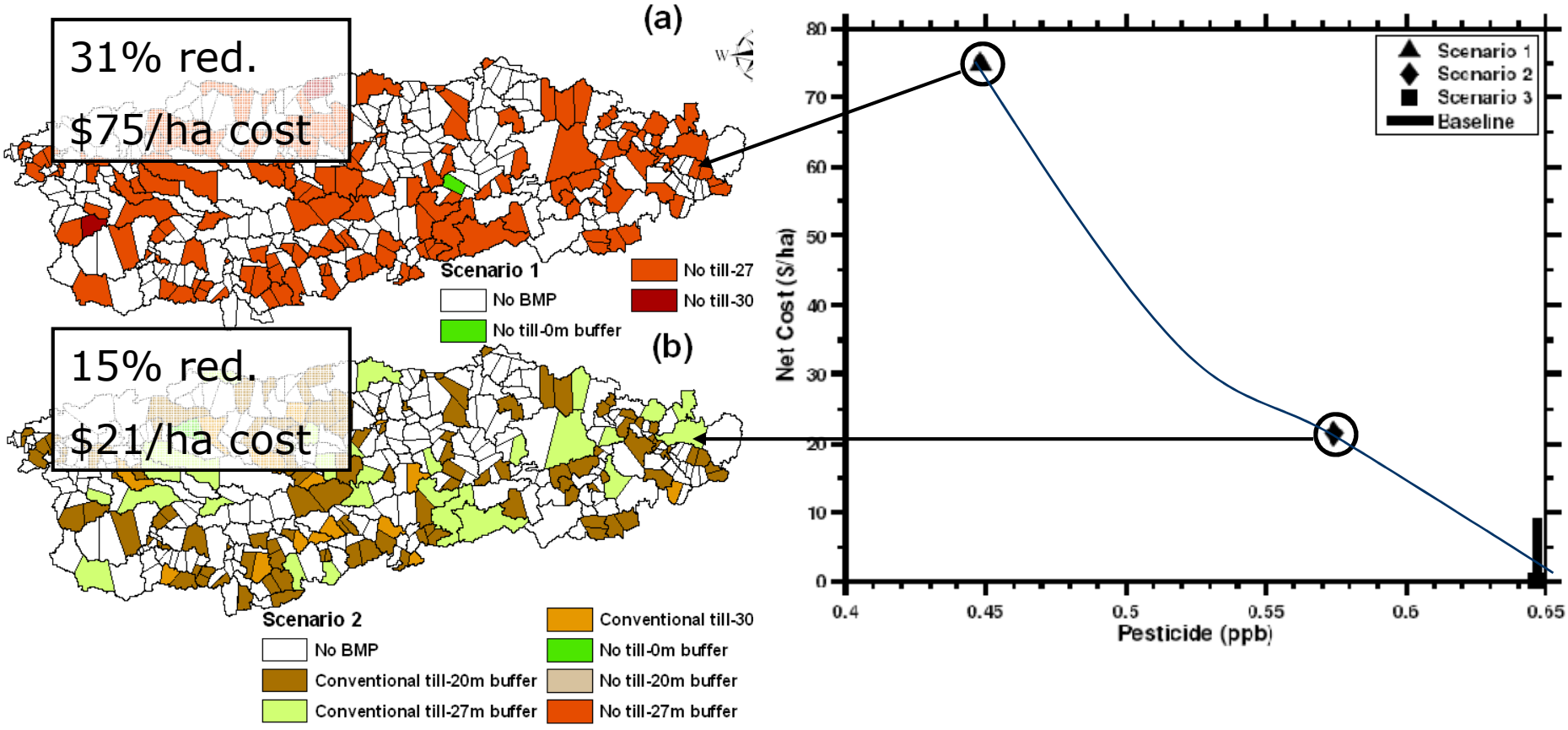
Progress of pareto-optimal front for pesticide model



Pareto-optimal front after the final generation



SWAT simulated atrazine yields at outlet of subbasin 9



Discussion of 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

Thank You
Questions???