Atrazine in the Midwest

- Application in US – **34,000 tons** in 2003
- Application rate – **85%** application in **corn**
- This application expected to increase in future to meet corn production for biofuel
- Concentration of atrazine in drinking water – **3 ppb** exceeded many days in Indiana
- Need to develop BMP strategies for atrazine control

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Corn

Sorghum
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

40 percentile subwatersheds
Optimization

- Global multi-objective optimization
  - Objective functions and constraints
  - Subjectivity

- Optimization algorithms
  - Genetic algorithms
  - Simulated annealing
  - Tabu search

![Graph showing optimization in two dimensions with objectives and constraints.](image)
Previous approaches to optimize BMP placement

- **Genetic Algorithms** (GAs) in combination with a watershed model used to optimize BMPs

- **Simultaneous** single objective optimization

- **Dynamic linkage** with the watershed model: limited application to small watersheds

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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: BMP optimization

- SWAT used to get the initial sediment loads

Multi-Objective GA with objective functions to:

1) Maximize pollution reduction in the watershed
2) Maximize the returns ($) from the watershed from BMP implementation

A set of alleles with all possible BMPs that can be applied in a field

Pareto-Optimal Solution
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\textsubscript{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

\[
y = 0.77x + 7.58
\]

\[R^2=0.75\]
SWAT calibration for pesticide
Allele set & BMP tool

<table>
<thead>
<tr>
<th>Crop</th>
<th>Allele set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>Buffer strip: 0, 20, 27, 30m, Conventional, and No-till</td>
</tr>
<tr>
<td>Soybean</td>
<td>‘Null’</td>
</tr>
<tr>
<td>Forest</td>
<td>‘Null’</td>
</tr>
<tr>
<td>Pasture</td>
<td>‘Null’</td>
</tr>
</tbody>
</table>

- 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)

1 2 3 4 5 6 7 8 9

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

31% red. $75/ha cost

15% red. $21/ha cost
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