# Cost Effective Placement of Conservation Practices in Watersheds: Integrating Economic and Biophysical Models

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# Outline

- An Economist's View on Voluntary Approaches

- Tools to support policy design
  - Integrated economic and watershed models
  - Evolutionary algorithms
  - Empirical study consider optimal placement of conservation practices

# An Economist's View

- Voluntary Approaches
  - Property rights with polluters
    - Agricultural producers have "right" to emit
    - Society must request change from industry
  - Different than pollution control in other sectors (US)
    - Air quality, noise pollution, zoning
    - Point sources of water quality

# An Economist's View

- If voluntary, do you need to pay to achieve adoption?
  - Public goods, externalities
  - Yes - if benefits to individuals do not cover the costs
    - Maybe not: landowner who loves wildlife is asked to adopt a practice that lowers her profit by a few dollars per acre, but increases bird populations in her locality a lot
    - Yes: Landowner who is worried about sending her son to college is asked to retire a profitable section of her land to reduce eutrophic conditions in an estuary 1000 miles away

# An Economist's View

- Policy Goals
  - Achieve desired reductions
  - Do so at least cost

- Cost
  - Cost includes lost output, direct costs of practices, increased risk, increased time, disagreeable visually, etc.
  - Also want to consider program costs
  - Who pays is different than what it costs

# Least Cost Problem

- What is the optimal placement of conservation practices to meet a given water quality improvement?
- What makes this challenging?
  - Multiple conservation practices with different effectiveness and costs are options
  - Multiple water quality endpoints (nitrogen, phosphorous, sediments, etc.)
  - Water quality effects from one field may be affected by choices on other fields

# Least Cost Problem

- Brute force strategy:
  - Using water quality/hydrology model, analyze all the feasible scenarios, picking cost-efficient solutions
  - But, if there are N abatement possibilities for each field and there are F fields, this implies a total of possible $N^F$ configurations to compare
  - 30 fields, 2 options → over 1 billion possible scenarios

# Strength Pareto Evolutionary Algorithm

Search technique to approximate pareto optimal frontier

Zitzler, Laumanns, and Thiele. "SPEA2: Improving the Strength Pareto Evolutionary Algorithm," TIK-Report 103, May 2001, Errata added September, 2001

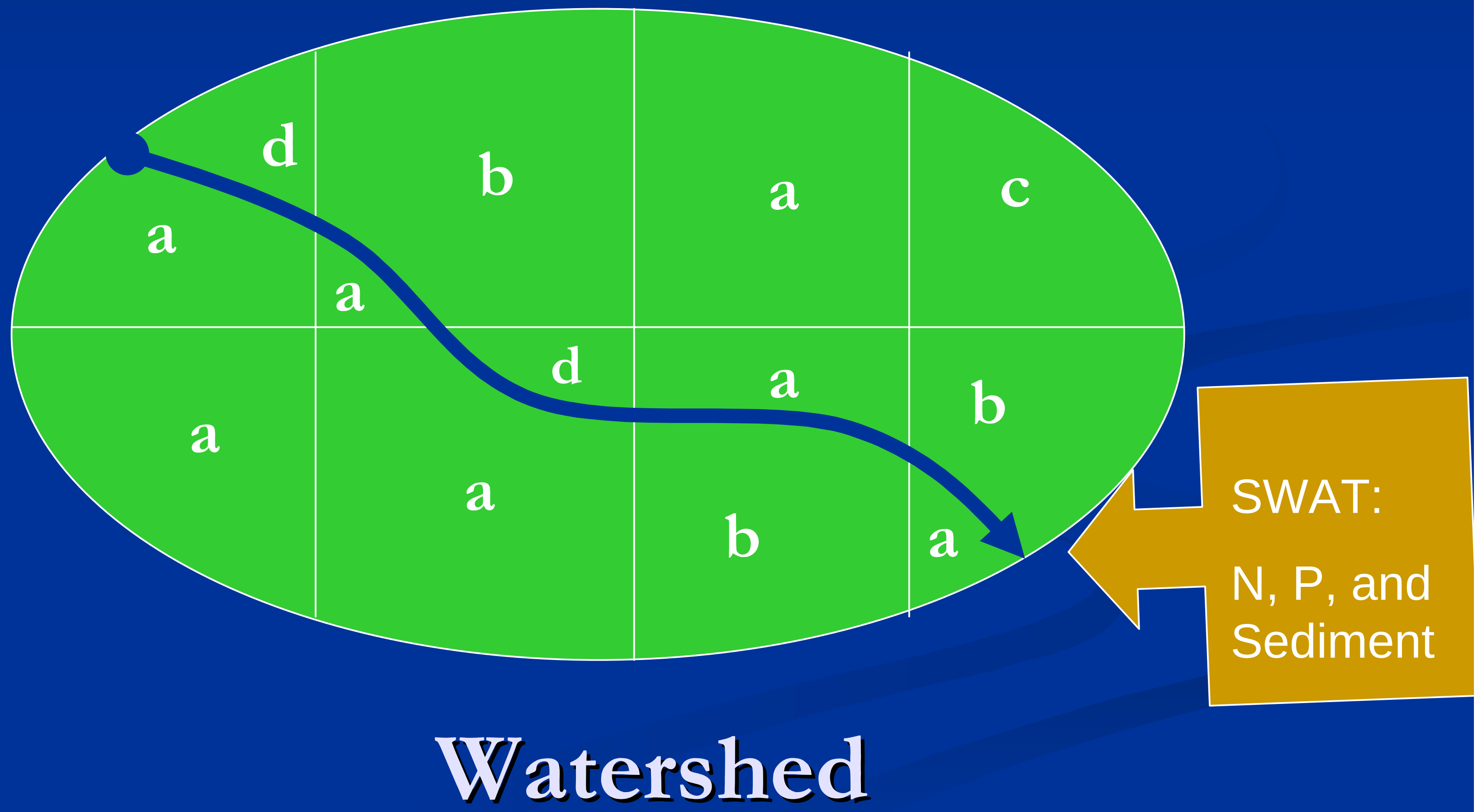
- Integrate Evolutionary Algorithm with water quality model
- Search for a frontier of cost-efficient nutrient pollution reductions

# Soil and Water Assessment Tool (SWAT)

- Watershed-scale simulation model developed by USDA - Agricultural Research Service
- Predicts ambient (instream) water quality associated with a spatially explicit set of land use/conservation practices
- Gassman et al. (2007) identify over 250 publications using SWAT

- 13 Fields, 4 landuse/abatement options: a, b, c, d

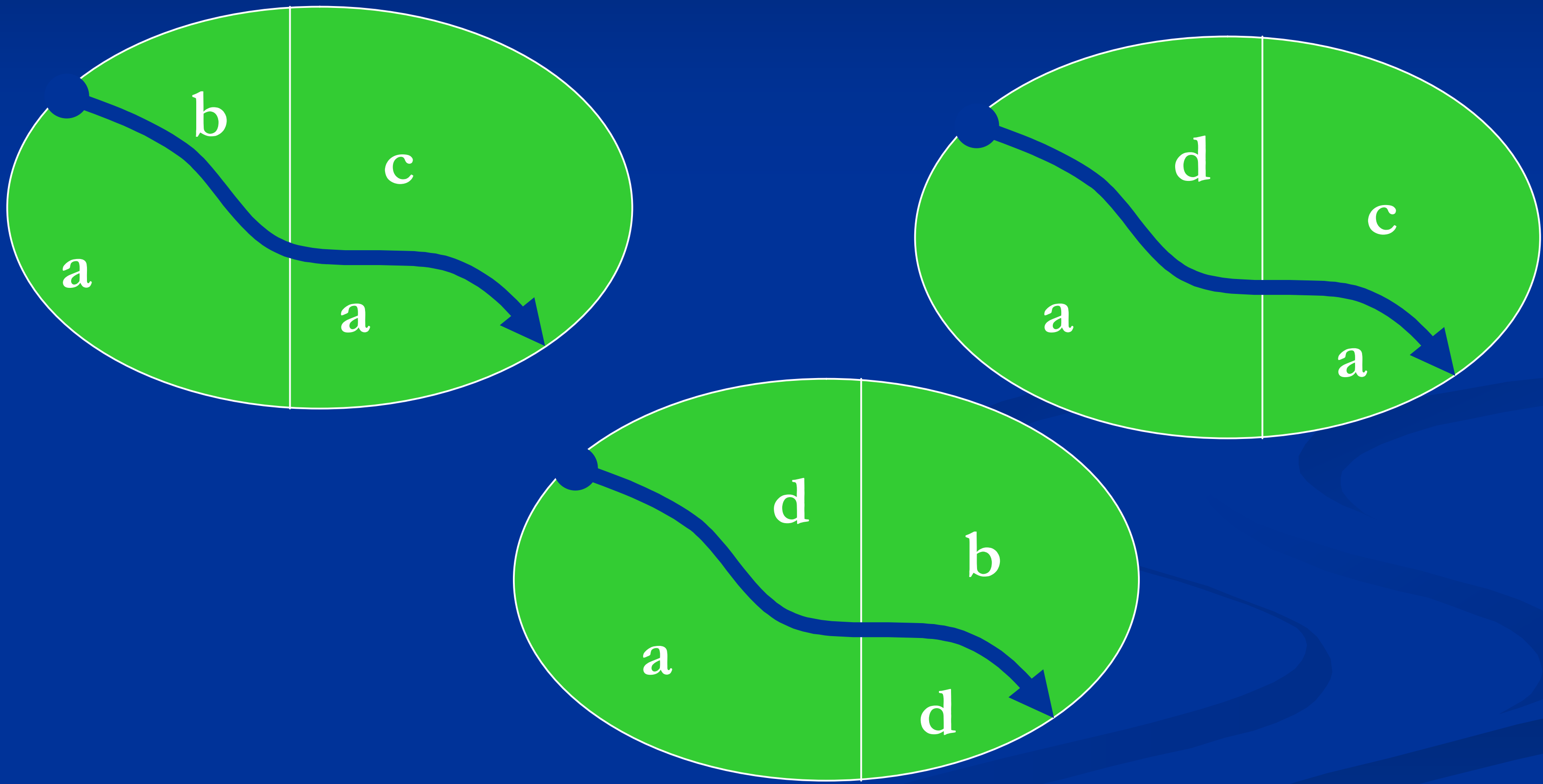
- SWAT simulates water quality under any combination of landuse/abatement activities



Individual = watershed configuration

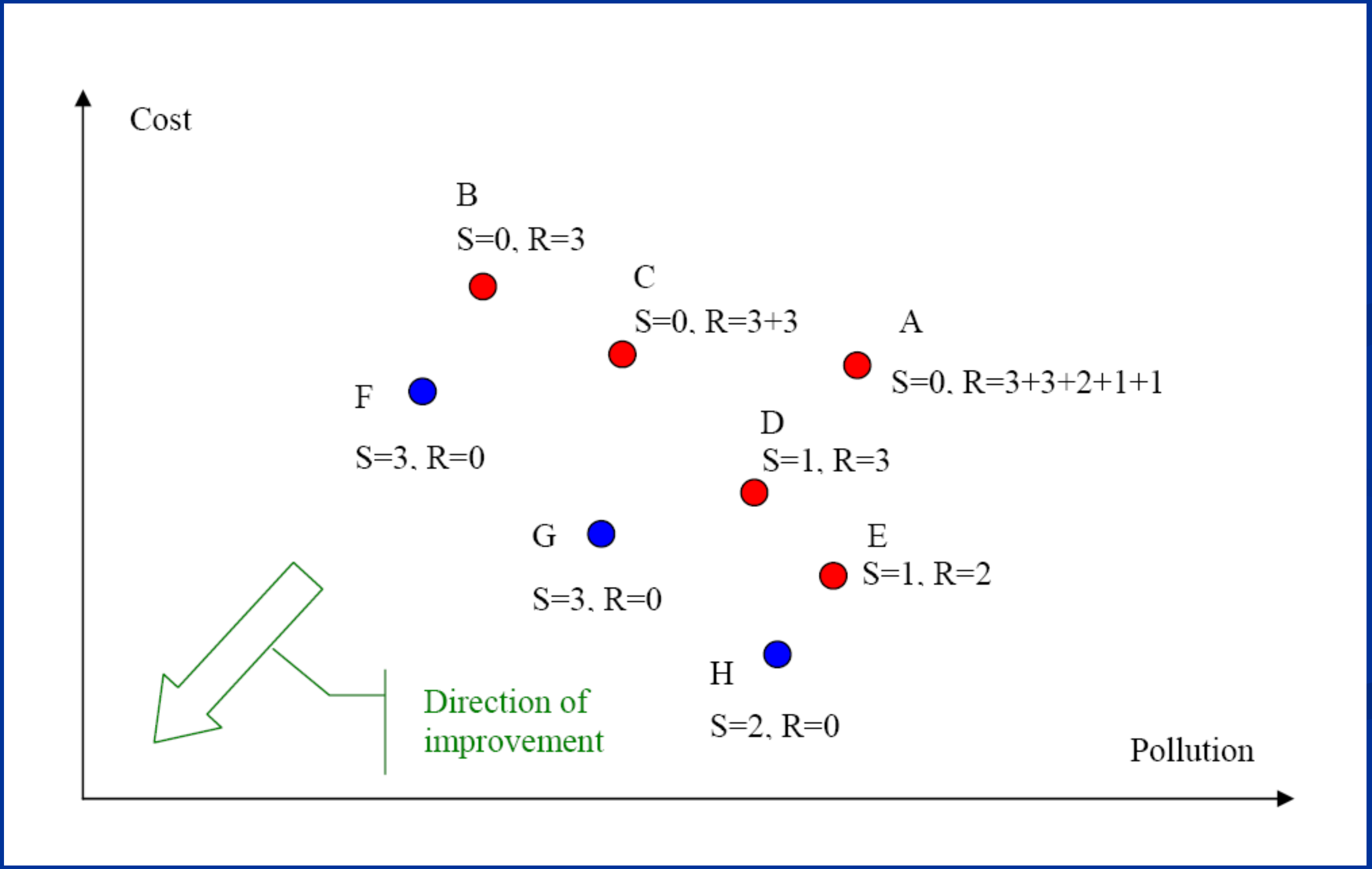
= specific assignment of practices to fields

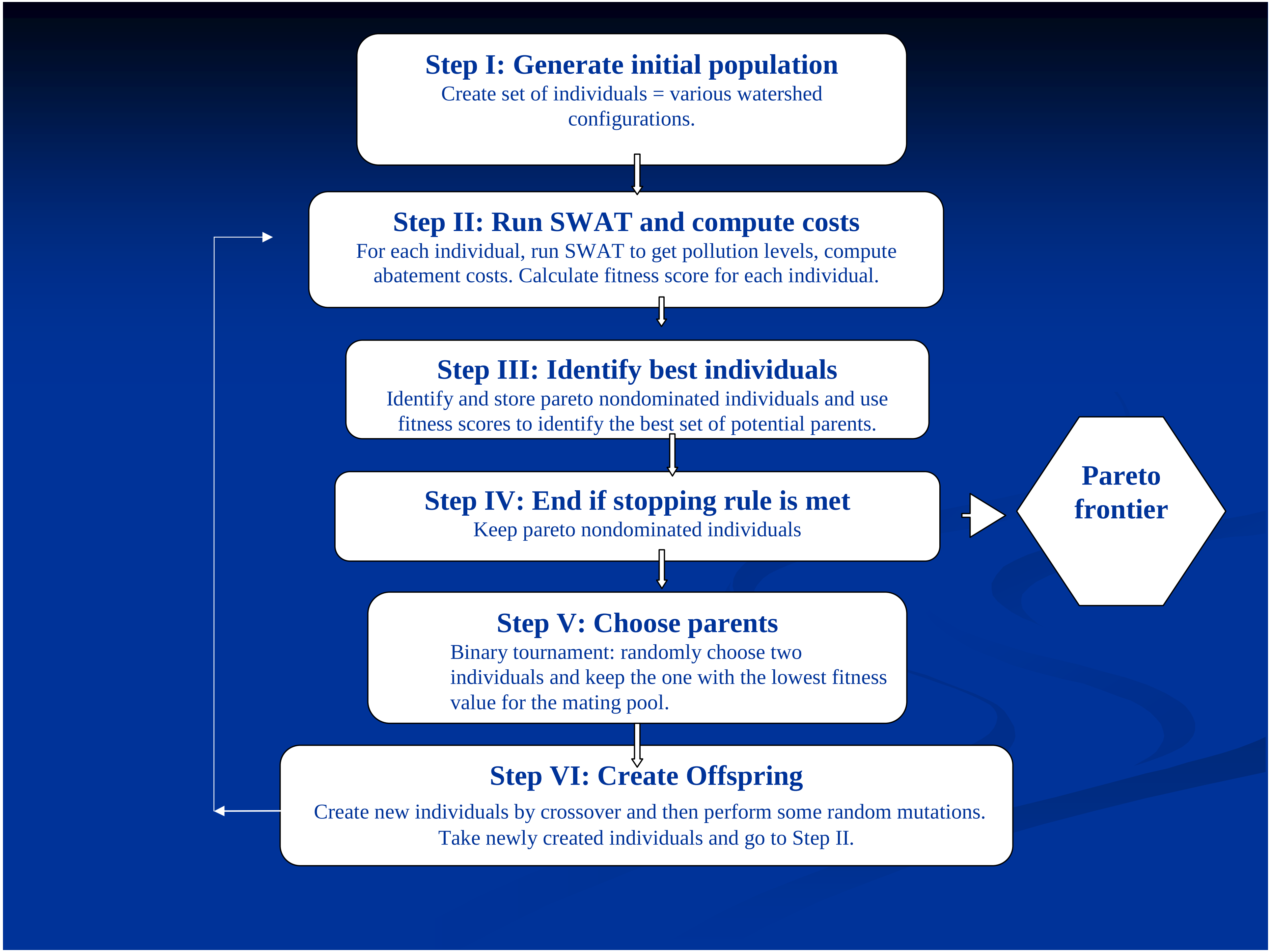
Population = set of watershed configurations



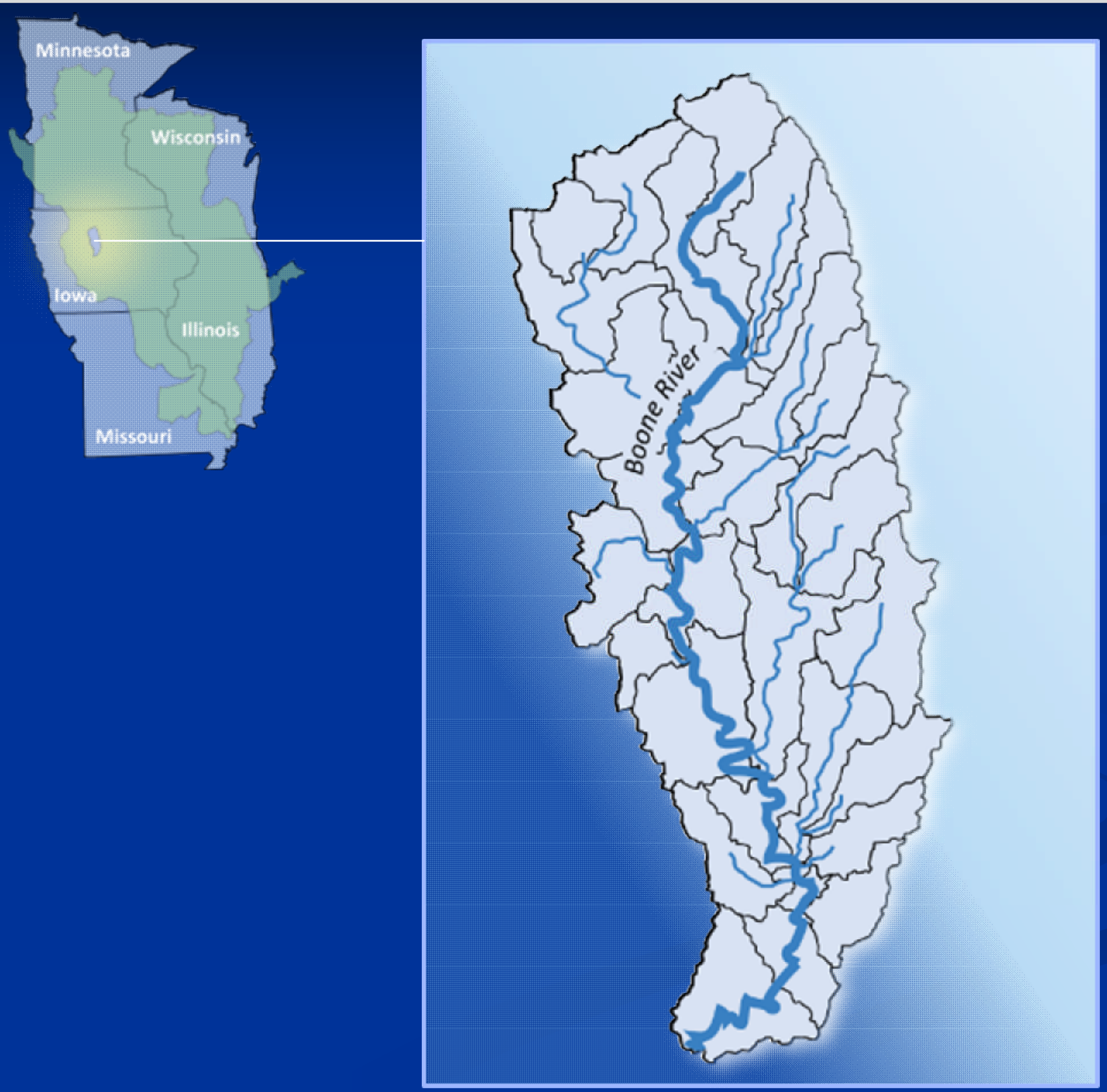
# Fitness assignment

- Strength S(*i*)= # of individuals *i* dominates
- Raw fitness R(*i*)= sum of strengths of individuals that dominate *i*
- Low value best: R(i)=0 means i is on the frontier




Step I: Generate initial population
Create set of individuals = various watershed configurations.
Step II: Run SWAT and compute costs
For each individual, run SWAT to get pollution levels, compute abatement costs. Calculate fitness score for each individual.
Step III: Identify best individuals
Identify and store pareto nondominated individuals and use fitness scores to identify the best set of potential parents.
Step IV: End if stopping rule is met
Keep pareto nondominated individuals
Pareto frontier
Step V: Choose parents
Binary tournament: randomly choose two individuals and keep the one with the lowest fitness value for the mating pool.
Step VI: Create Offspring
Create new individuals by crossover and then perform some random mutations.
Take newly created individuals and go to Step II.

# Boone River Watershed Iowa



# Boone River Watershed

- 237,000 ha (~586,000 acres ~ 915 mi$^2$)
- Extensively tile drained, few wetlands remaining
- Corn and soybeans cover nearly 90%
- 128 CAFOs --- 109 swine operations produce about 480,000 head annually
- Manure from livestock and commercial fertilizer are the primary sources of nutrients to the streams

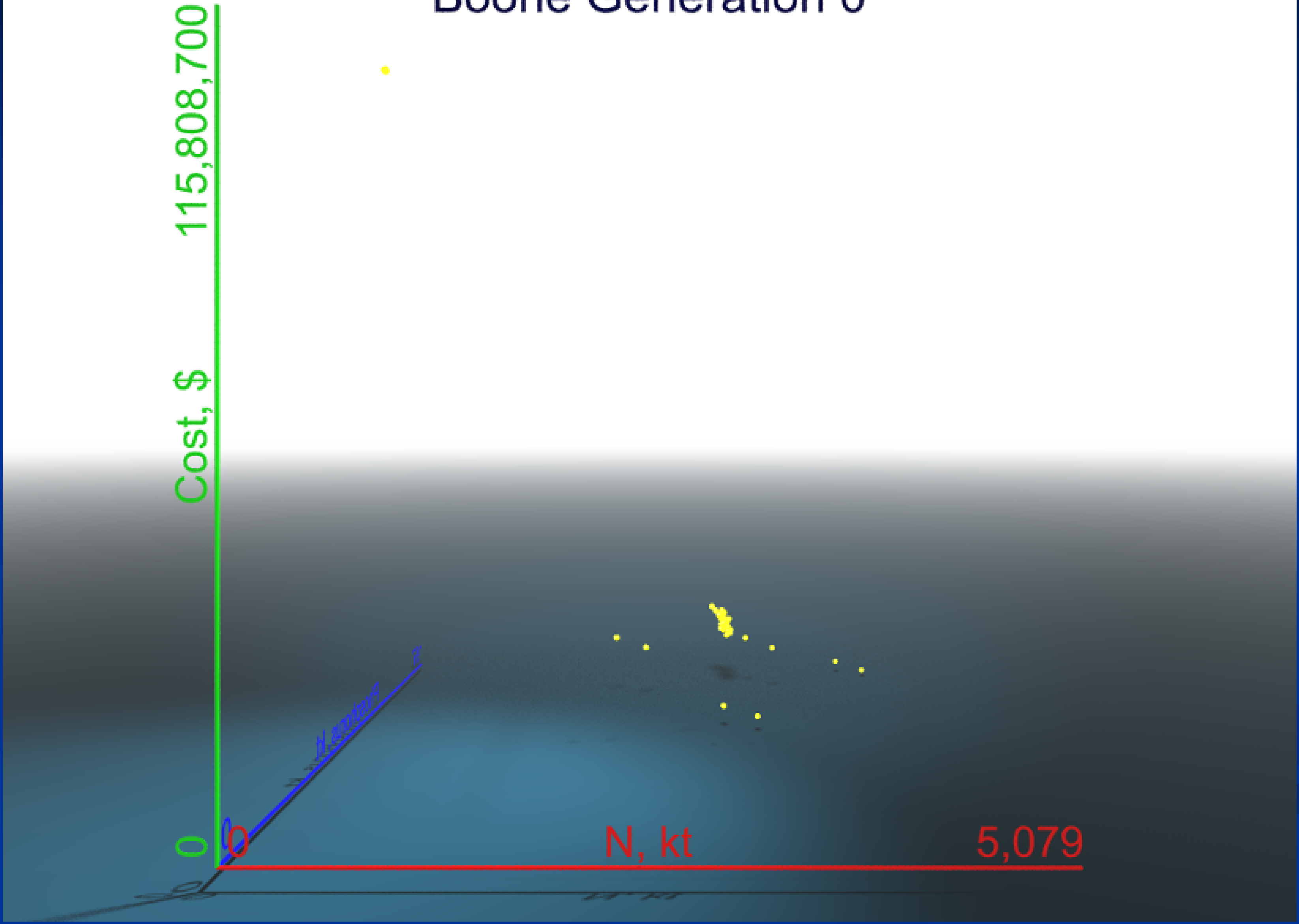
# Common Land Unit Boundaries

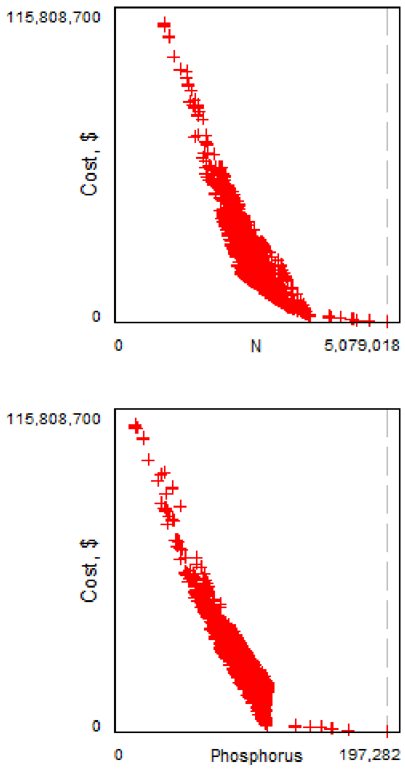
- 16,430 distinct CLUs
- Detailed data related to:
  land use,
  farming practices,
  production costs,
  slope,
  soils,
  CSRs, etc.
- Weather station data

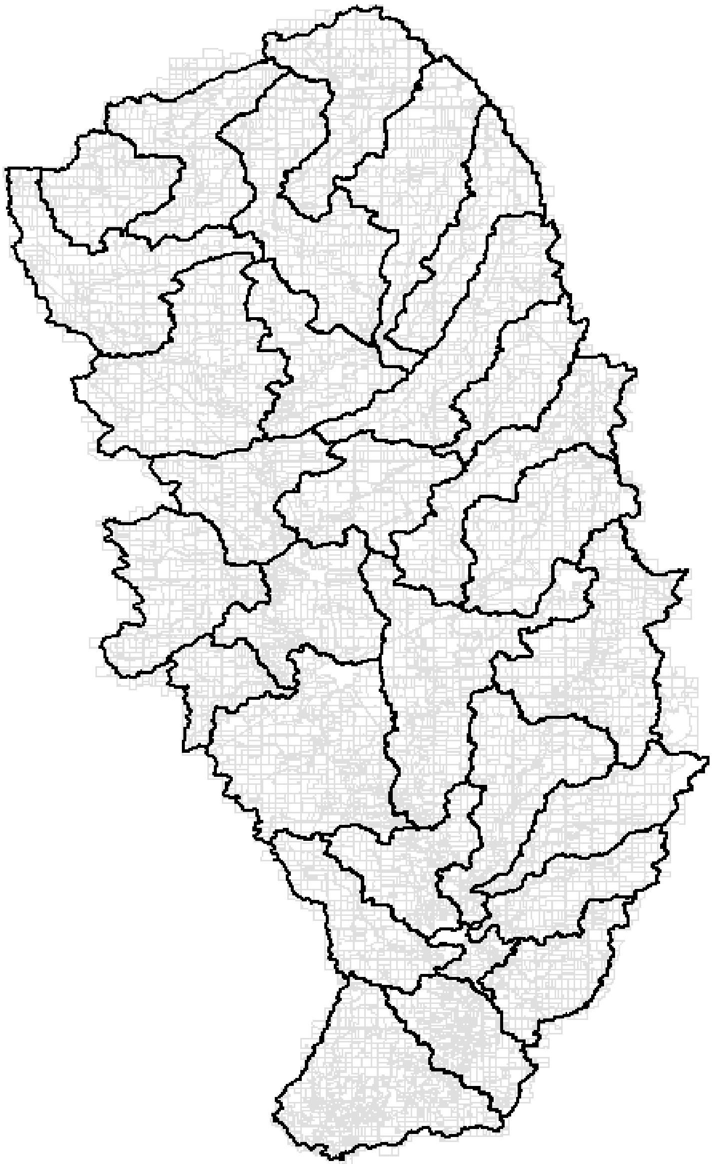
# The Land use/Abatement Set

- For each CLU
  - Current practice
  - Land retirement
  - No tillage
  - Reduced fertilizer (20%)
  - Cover crops
  - Sensible combinations

# Boone Generation 0





Boone Individual 0001

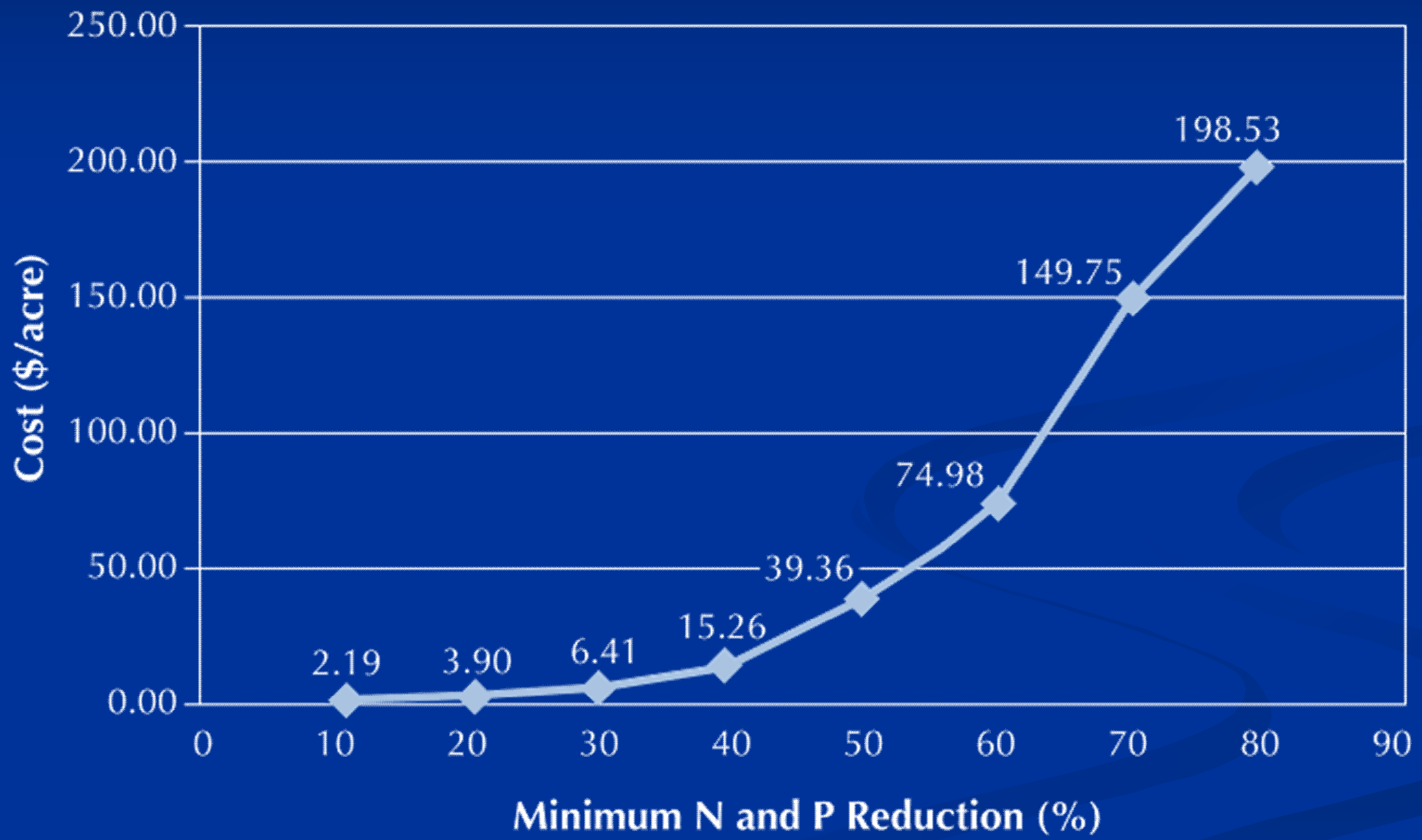
N 4,837,160.0
Phosphorus 187,888.0
Cost $0.00

Baseline
NT
Cover Crop
Cover Crop NT
RF
NT RF
Cover Crop RF
Cover Crop NT RF
CRP

# Gains from Optimal Placement

| | | | | Practice Allocation (%) | | | | |
|---|---|---|---|---|---|---|---|---|
| | Cost ($1000 dollars) | % N | % P | NT | NT, RF | CC, RF | CC NT RF | Other |
| Cover Crops, Red. Fert | 15,380 | 29 | 32 | | | 100 | | |
| Same N reductions | 2,778 | 29 | 44 | 84 | 13 | <1 | <1 | 3 |
| Same Cost | 15,365 | 47 | 45 | 8 | 23 | <1 | 64 | 5 |

Per acre average costs of abatement actions needed to achieve equal percent reductions in N and P



# THANK YOU!