Designing Practice Based Approaches for Managing Agricultural Nonpoint-Source Water Pollution

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U.S. Water Quality: Lakes

- Lakes, Reservoirs, Ponds:
  - 42% assessed, 65% inadequate water quality to support uses
  - Over 11 million acres are “impaired”
  - Agriculture third highest source of impairment

The diverse aquatic vegetation found in the Littoral Zone of freshwater lakes and ponds.

A cyanobacteria bloom in a Midwestern lake.

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Water Quality: Rivers & Streams

Photos courtesy Iowa DNR

- Rivers and Streams:
  - 26% assessed, 50% inadequate water quality to support designated uses
  - Nearly ½ million stream miles are “impaired”
  - Agriculture leading source of impairment (identified as cause of 22% unknown second highest)

Time trend

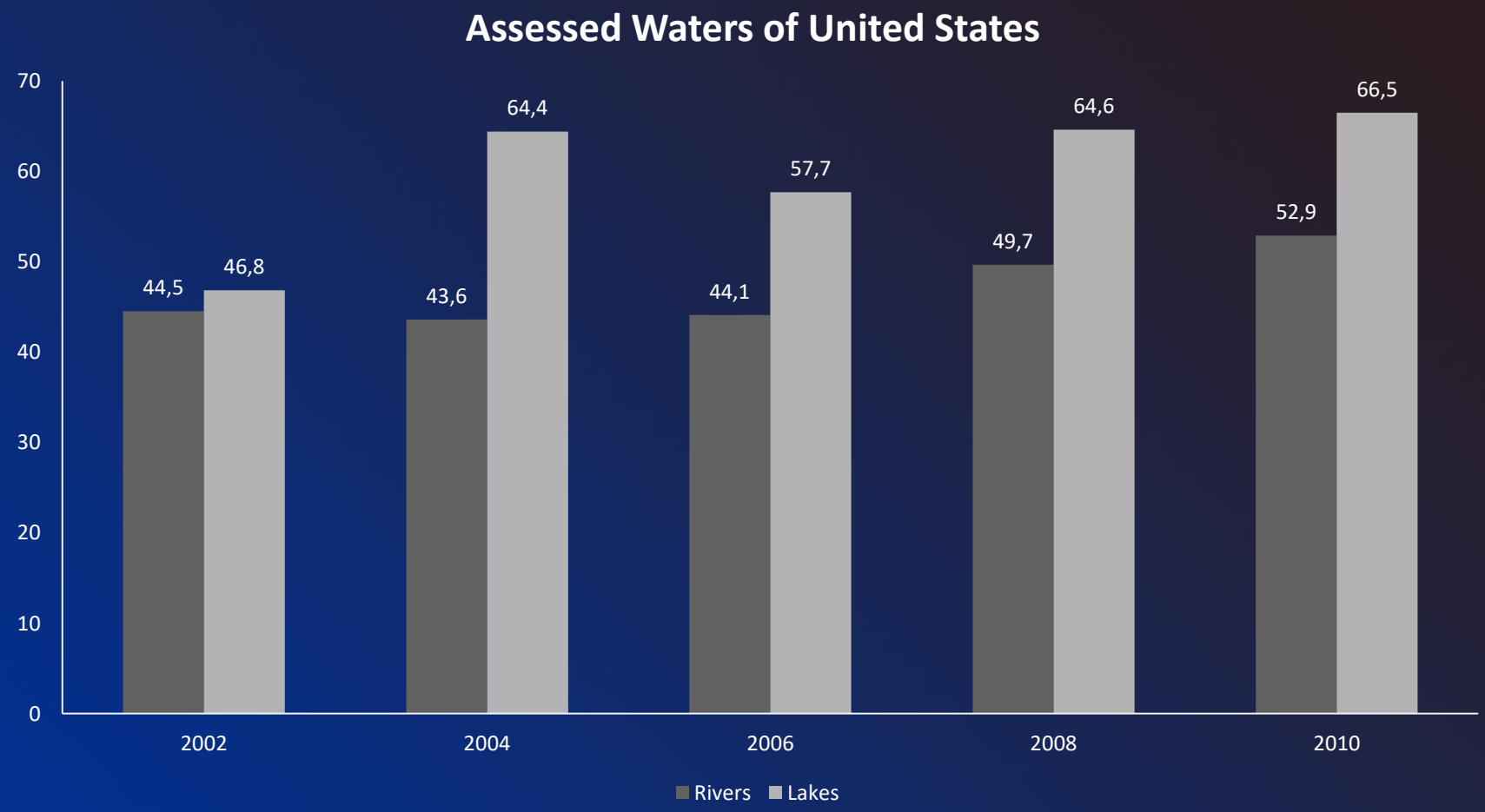


Figure 1. US waters assessed as impaired

Source: EPA National Summary of Assessed Waters Report

What abatement options exist? Examples from U.S. Agriculture

- In field Management Practices
  - Reduced (no) tillage
  - Manure, fertilizer management/reduction
  - Cover crops, rotation changes
  - Land retirement
- Structural Practices
  - Buffers
  - Grassed Waterways
  - Denitrification, controlled drainage
  - Wetland restoration

Conservation practices

Land Retirement

Panoramic view of gamma grass-big blue stem planting

http://www.fsa.usda.gov/Internet/FSA_Image/ia_767_15.jpg

Wetlands Restoration

Photo courtesy Missouri NRCS

Efficacy and Cost of Practices

- Vary by
  - Pollutant
  - Field characteristics
  - Land use in watershed
  - Provision of other ecosystem services
- Ideally, all of these factors considered in efficient policy design

In sum, have to deal with all of these aspects

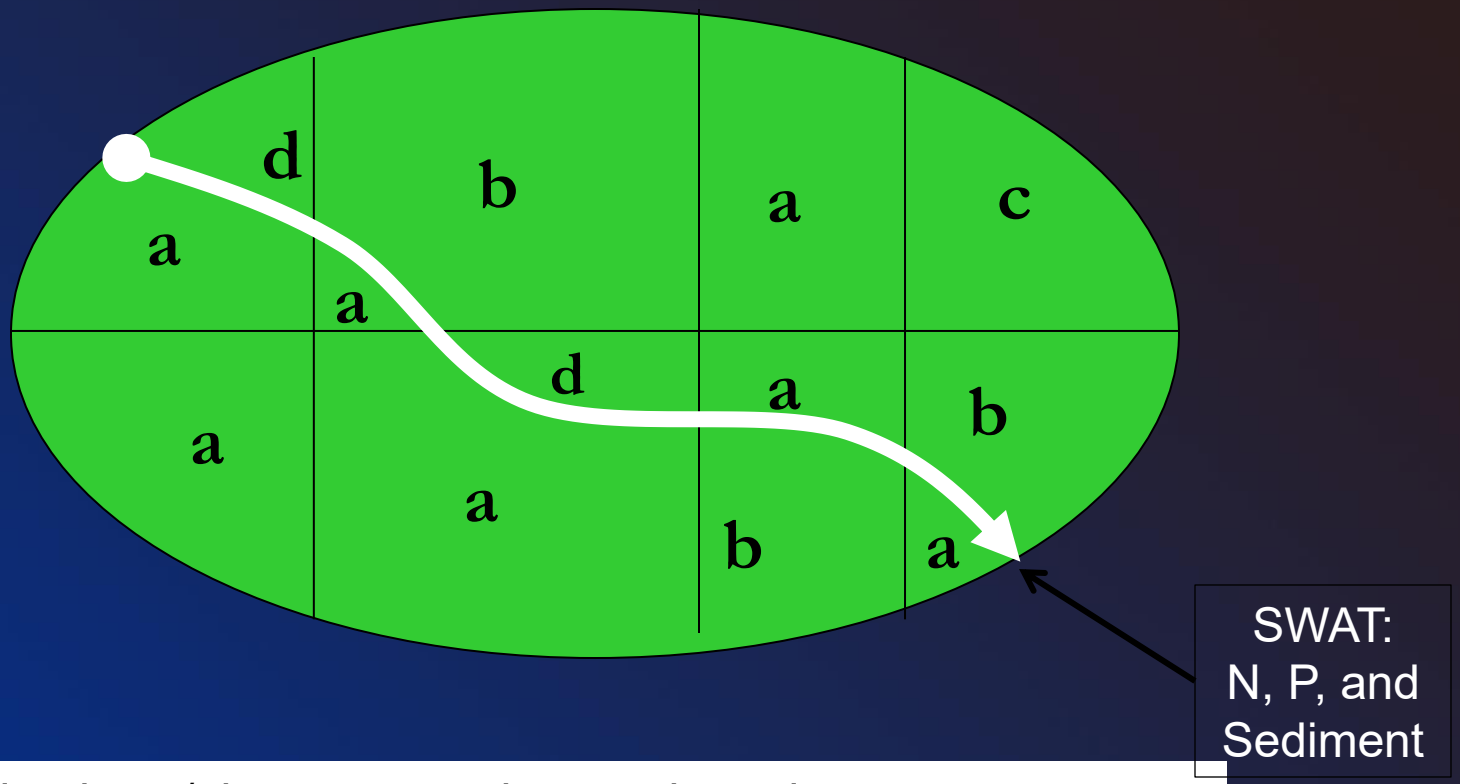
- Enormous number of farm fields/decision makers
- Each : one or more land use/conservation practices

  Retire land (e.g., CRP), Reduce tillage, Terraces, Contouring, Grassed Waterways, Reduce fertilizer, better timing, etc.
- Costs and effectiveness vary across locations
- HOW? Use models to guide policy

Soil and Water Assessment Tool

- 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

Watershed



- 13 Fields, 4 land use/abatement options: a, b, c, d
- SWAT simulates water quality under alternative land use, abatement activities

Least Cost Problem

- What is the optimal placement of conservation practices?

- 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 NF configurations to compare
  - 30 fields, 2 options → over 1 billion possible scenarios!

Strength Pareto Evolutionary Algorithm

Search technique to approximate pareto optimal frontier

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

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

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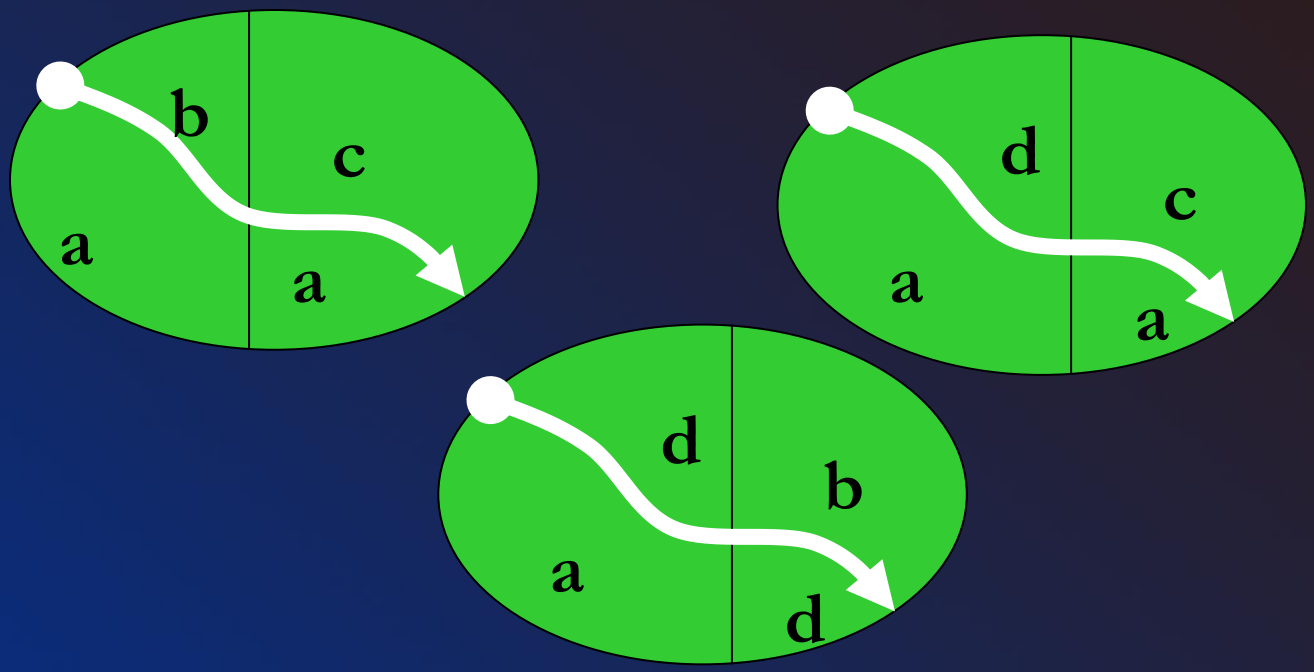
Terminology



"Individual" = specific assignment of practices to fields

"Population" = set of individual watershed configurations

SPEA2 Applied to Optimal Watershed Design

Step I: Generate initial population

Step II: Run Swat and compute costs

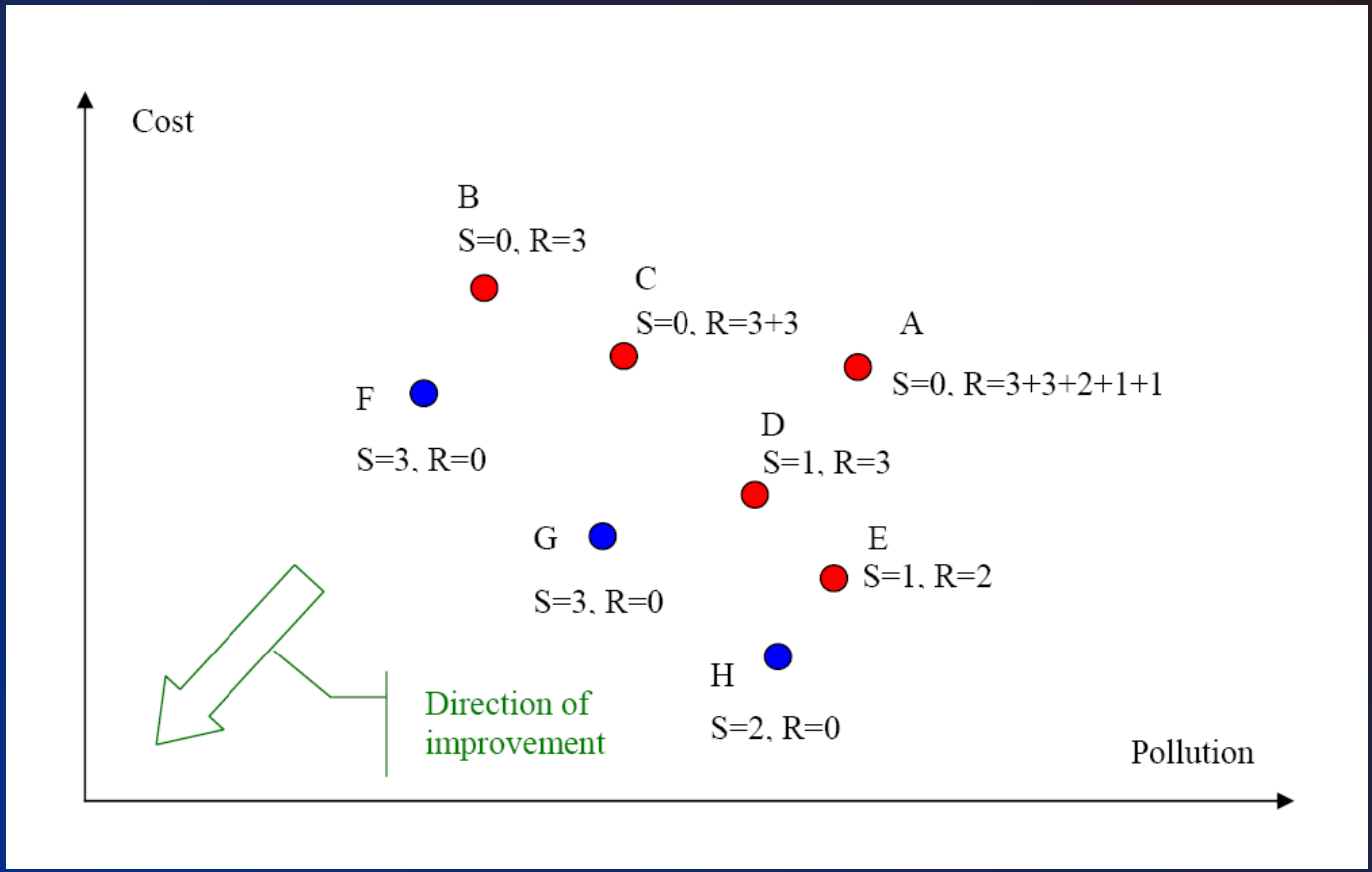
Step III: Identify best individuals

Step IV: Evaluate stopping rule → **Pareto frontier**

Step V: Choose parents

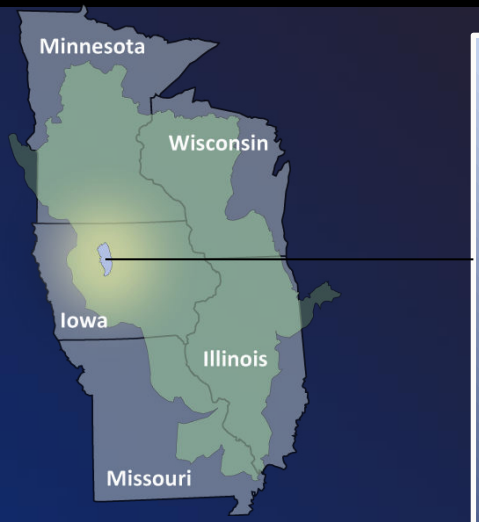
Step VI: Create offspring

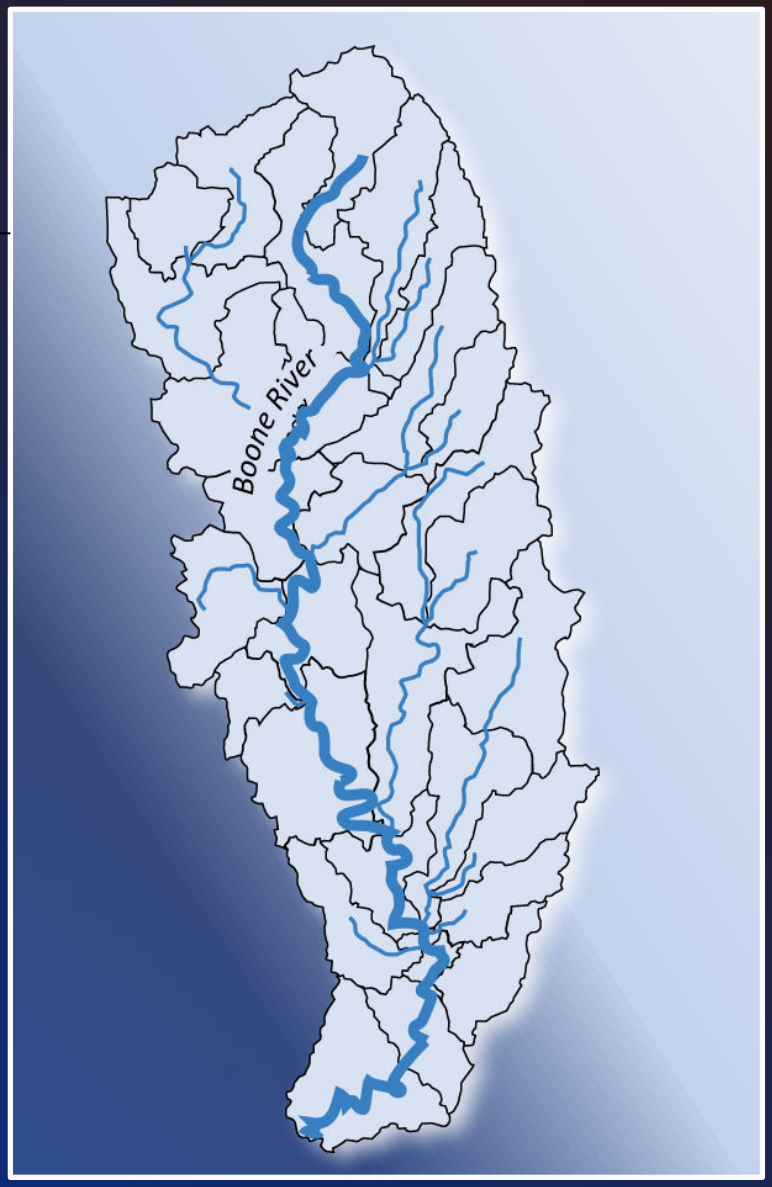
Pareto Frontier



- 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

Boone River Watershed Iowa





- ~586,000 acres
- tile drained, 90% corn and soybeans
- 128 CAFOs (~480,000 head swine)

Natural Environment: Boone

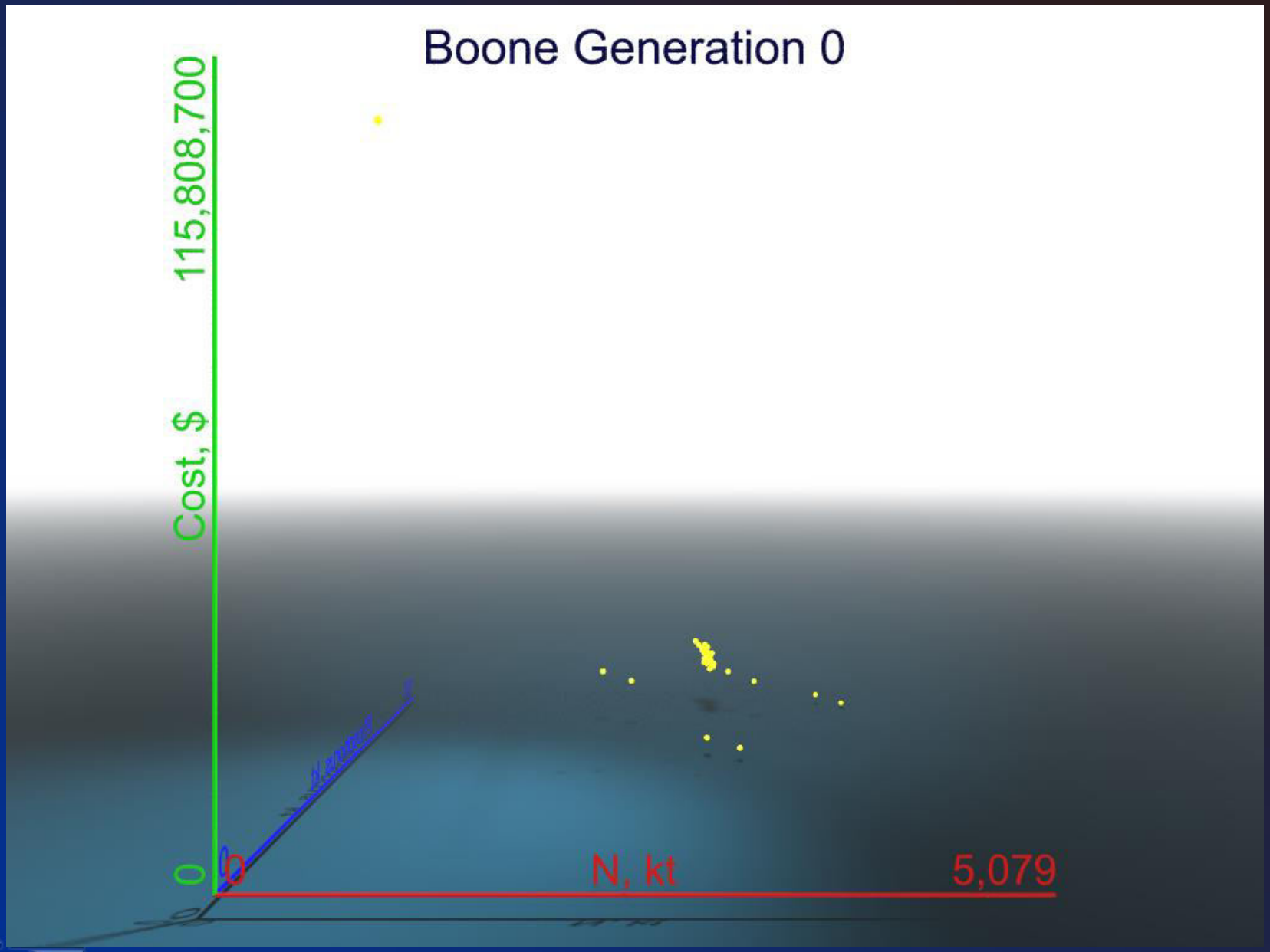
- Some of the highest N loads in Iowa
- TNC priority area biodiversity
- Iowa DNR Protected Water Area

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

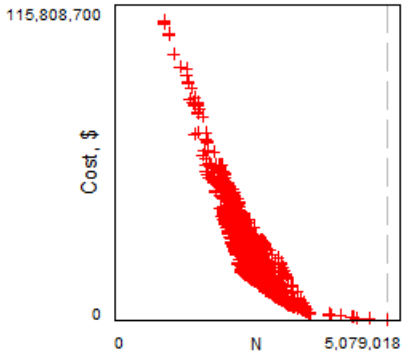
The Land use/Abatement Set

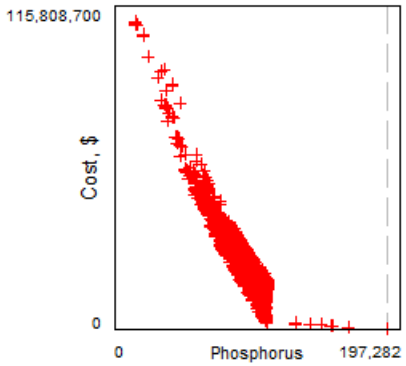
- For each CLU
  - Current practice
  - Land retirement
  - No tillage
  - Reduced fertilizer (20%)
  - Cover crops
  - Sensible combinations

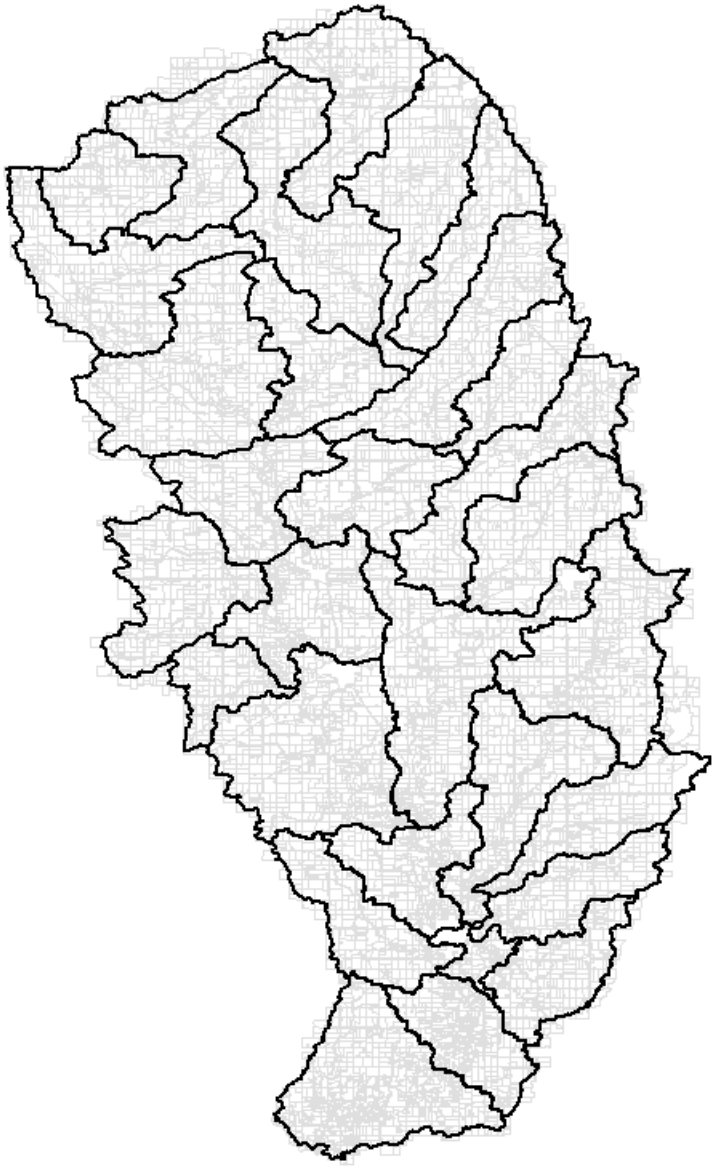

Boone Generation 0
115,808,700
Cost, $
0
0
N, kt
5,079

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







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

Least Cost for N and P Reductions

Target % Decrease	Cost ($1,000)	Cost ($/acre)	Reduction (%) N	Reduction (%) P	Watershed practices (counts of HRUs) Baseline	NT	CC	CC, NT	RF	NT, RF	CC, RF	CC, NT, RF	Retire Land
10	1,158	2.19	11	21	1781	795	4	0	2	311	3	4	2
20	2,064	3.90	21	33	580	2310	4	2	1	1	2	0	2
30	3,389	6.41	30	44	1	2398	1	3	3	382	5	107	2
40	8,072	15.26	40	45	7	9	4	90	3	2173	5	608	3
50	20,815	39.36	50	50	5	10	5	11	12	966	11	1635	247
60	39,651	74.98	60	60	6	3	5	3	9	213	8	1828	827
70	79,194	149.75	70	81	4	61	2	369	2	417	5	3	2039
80	104,993	198.53	80	89	4	8	3	91	7	1	6	2	2780

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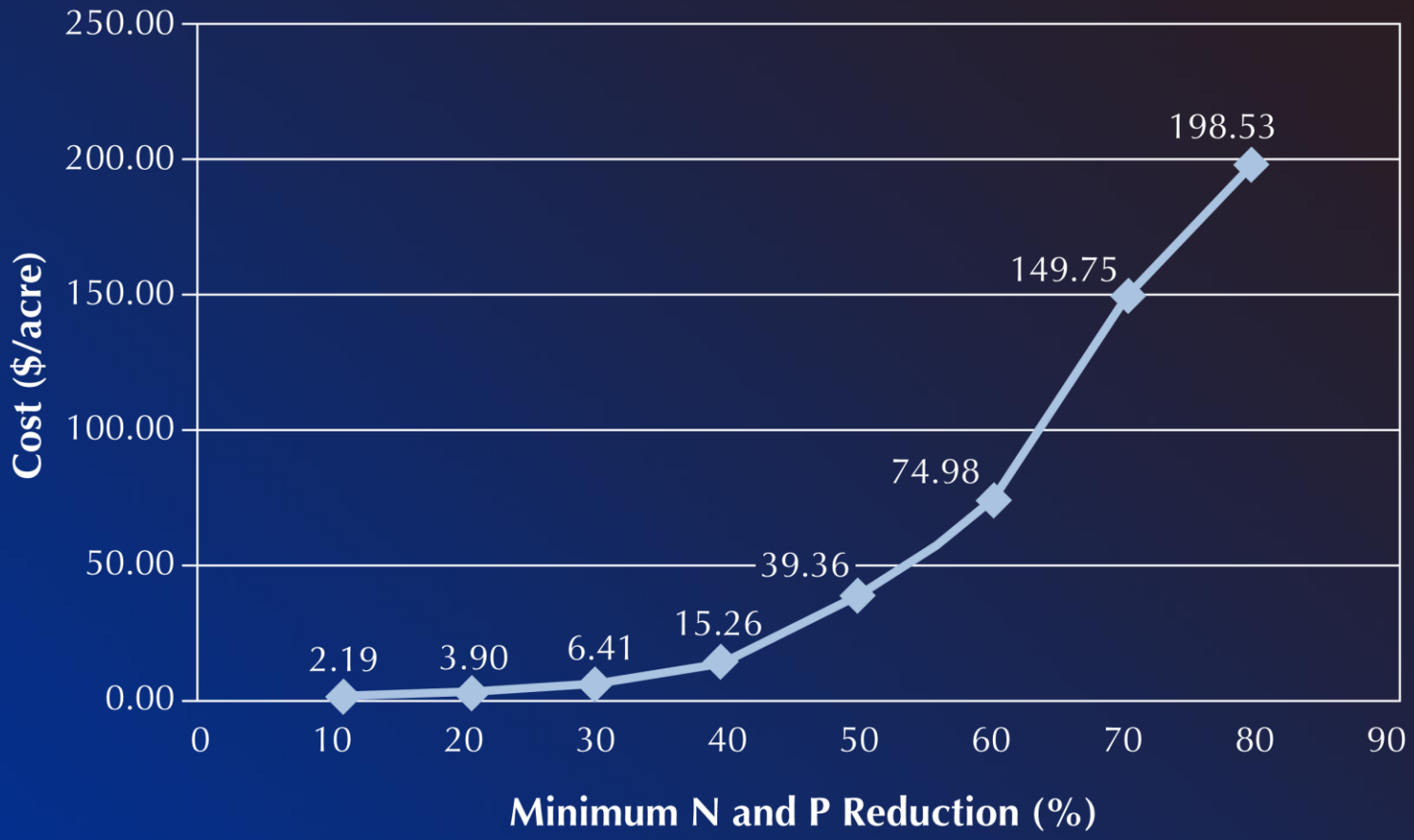
Per acre average costs of abatement actions needed to achieve equal percent reductions in N and P



Policies to Attain Nutrient Reductions

- Taxes (or subsidies)
- Voluntary Approaches (may be with financial incentives)
- Regulations
  - Technology requirements
  - Standards (permits)
  - Permit trading, “cap-and-trade,” “offsets”
  - Other (compliance requirements, labeling requirements)

Regulation types

- Technology Requirements: required to adopt specific method of production or technology
  - catalytic converters,
- Standards: required to have a permit to cover their emissions or meet a standard
  - zoning requirements
- Firms may be allowed to buy and sell permits from one another
- Compliance Requirements

Property rights with polluters

- Cost share programs - voluntary
  - Conservation Reserve Program,
  - Environmental Quality Improvement Program,
  - Conservation Security Program, and
  - Wetlands Reserve Program , etc.
- Reverse auctions
- Offsets (baseline and trade)
- Labeling, consumer information programs
- Conservation compliance

Property rights with society

- Approach for many pollutants
  - Industrial sources air pollution
  - Point sources water pollution
  - Smoking bans, etc.
- Policies that are consistent with:
  - Cap and trade (capped sectors)
  - Regulatory requirements

BMPs: Everglades Agricultural Area

- 718,000 acres (40 acre fields)

- Everglades Regulatory Program
  - goal 25% P reduction overall
  - mandatory BMPs, 1995
  - Implemented via points
    - flexibility in BMPs, 25 points/farm
    - expert judgment set point values
    - must implement and monitor WQ

Wikipedia

EAA Regulatory Program

- Property Rights: with citizens
- First 3 years: 55% P load reduction (SFWMD, 1998)
- Unable to find information on costs
  - Direct cost of BMPs
  - Lost profit
  - Cost of monitoring
  - Cost of program implementation

Comments and Questions Welcome!

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