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Big Creek as a Laboratory for a Virtual Watershed

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Christopher Lant is Professor of Geography and Environmmental Resources, co-Director of the Enviornmental Resources and Policy Ph.D. program and Executive Director of the Universities Council on Water Resources. His extensive research experience is in watershed management and integrative modeling, and in environmental policies related to polluted runoff, wetlands, and provision of ecosystem services.

Virtual Watershed

NSF *Biocomplexity in the Environment* Program 2004-2008

Christopher Lant (*Geography*) PI
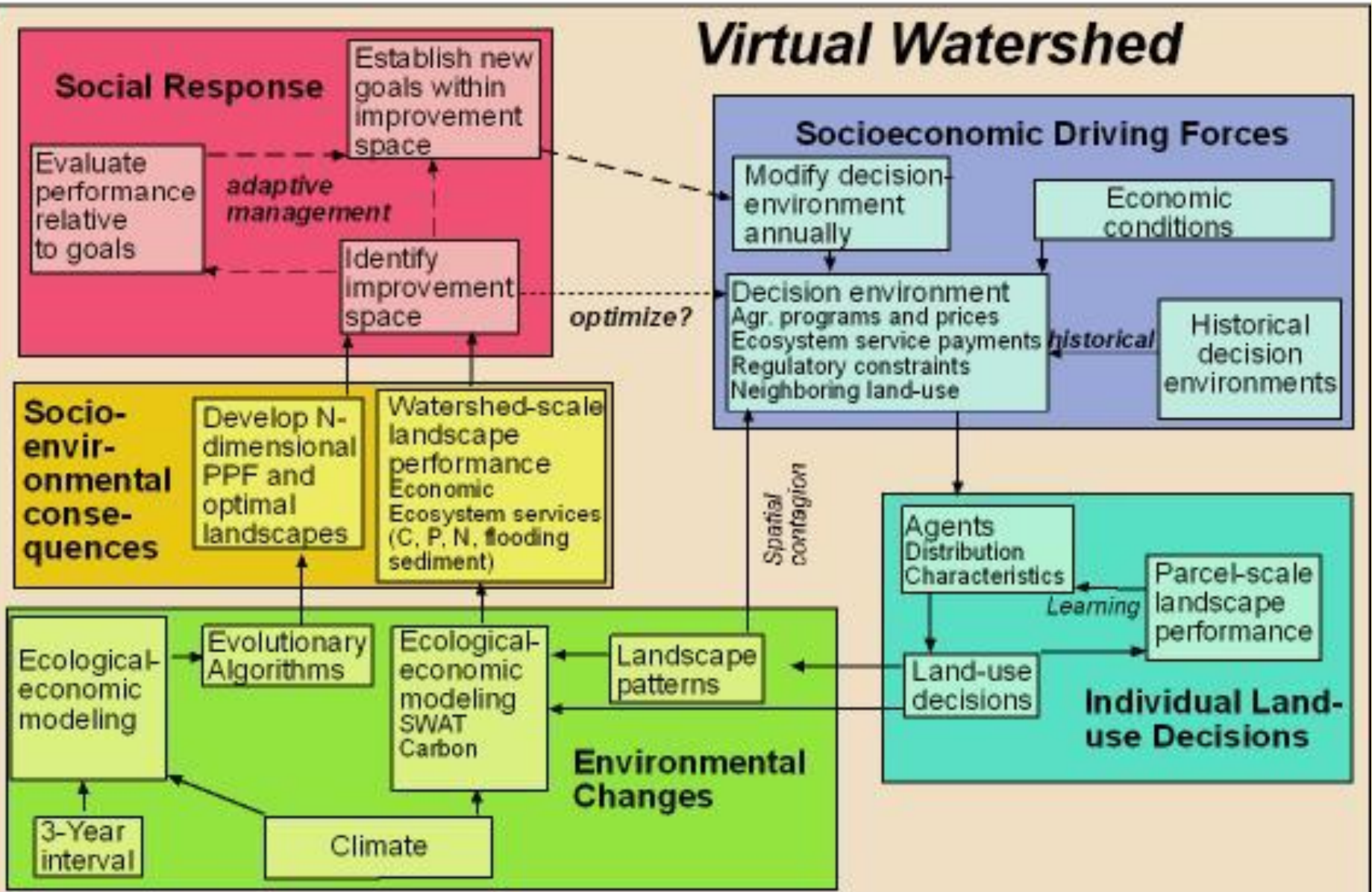
Steven Kraft, Jeff Beaulieu (*Agr. Economics*)

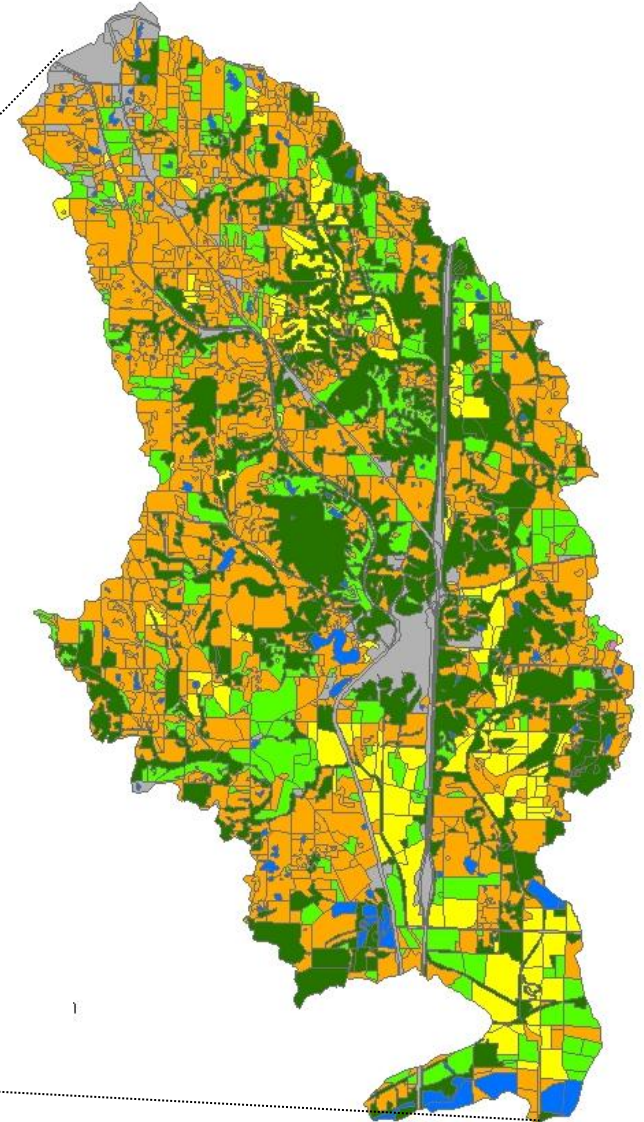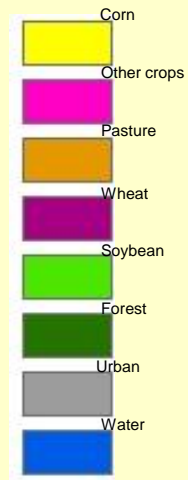John Nicklow (*Civil Engineering*)
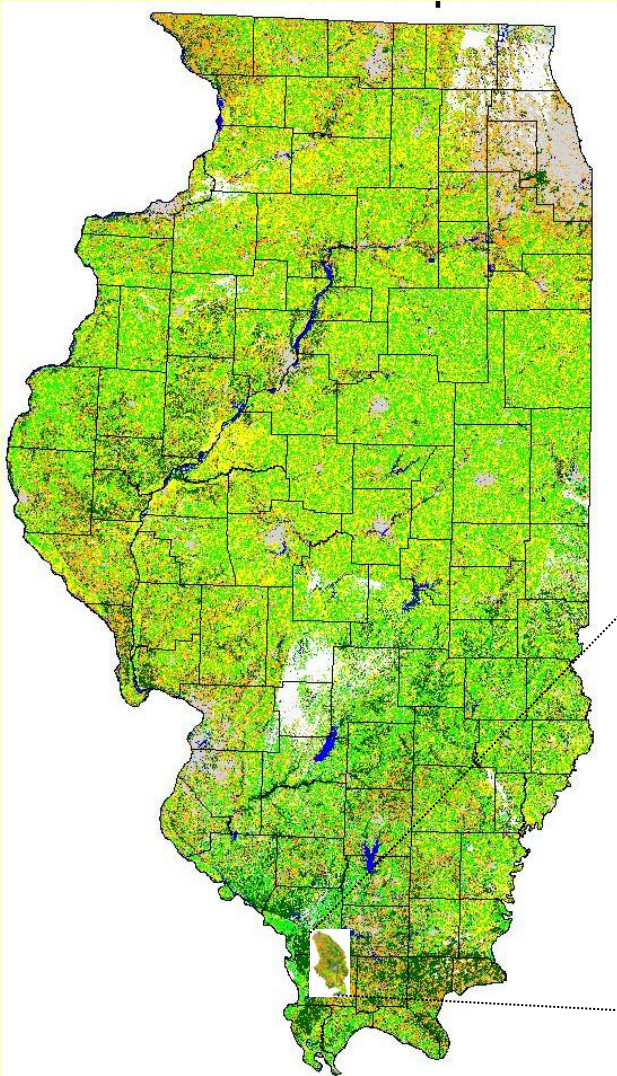
Michelle Zhu (*Computer Science*)

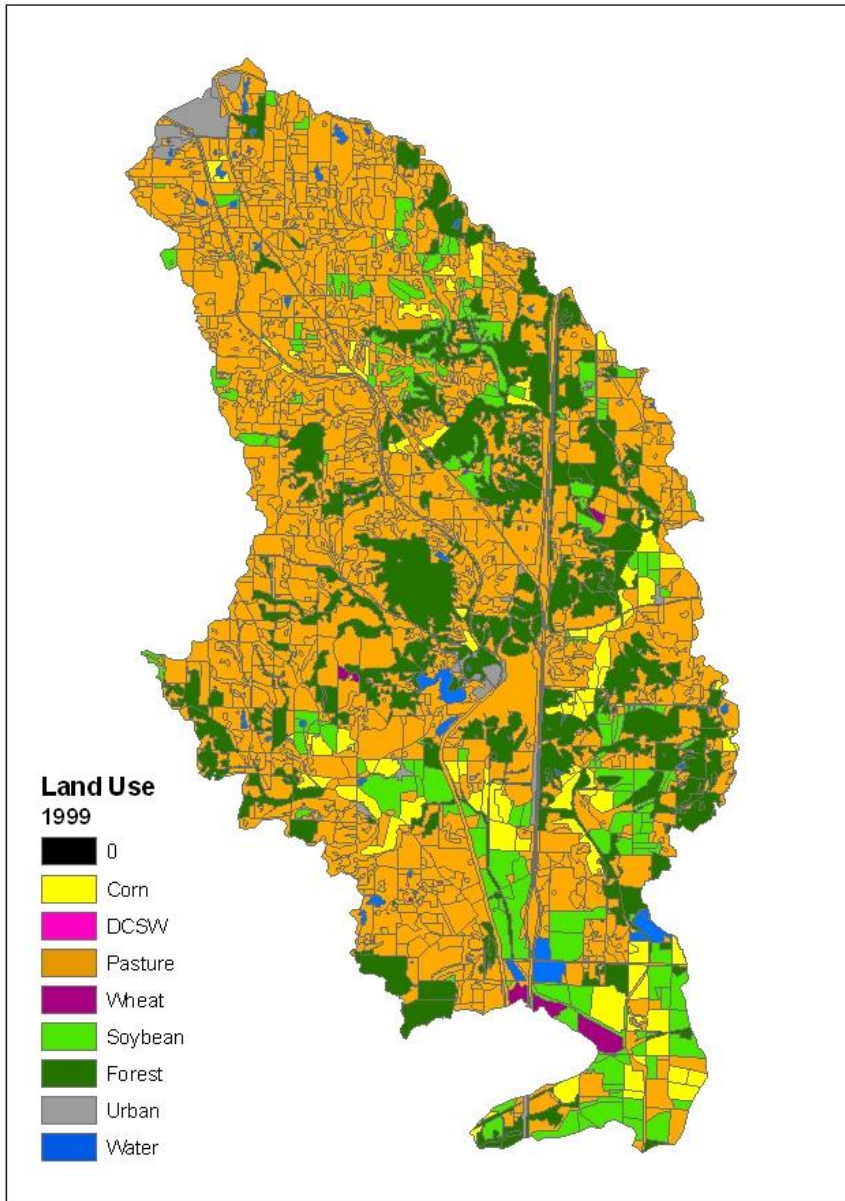Raja Sengupta (*Geography*) McGill

George Malanson (*Geography*) Iowa

The Modeling Approach

Virtual Watershed

Social Response
- Establish new goals within improvement space
- Evaluate performance relative to goals
- *adaptive management*
- Identify improvement space

optimize?

Socioeconomic Driving Forces
- Modify decision-environment annually
- Economic conditions
- Decision environment
  Agr. programs and prices
  Ecosystem service payments *historical*
  Regulatory constraints
  Neighboring land-use
- Historical decision environments

Socio-environmental consequences
- Develop N-dimensional PPF and optimal landscapes
- Watershed-scale landscape performance
  Economic
  Ecosystem services
  (C, P, N, flooding sediment)

Spatial contagion

Individual Land-use Decisions
- Agents Distribution Characteristics
- Parcel-scale landscape performance
- *Learning*
- Land-use decisions

Environmental Changes
- Ecological-economic modeling
- Evolutionary Algorithms
- Ecological-economic modeling SWAT Carbon
- Landscape patterns
- 3-Year interval
- Climate

Land Use is the Lynchpin Between
Social Factors and Environmental Results

Corn
Other crops
Pasture
Wheat
Soybean
Forest
Urban
Water

1999 Landuse Polygon Classification

Land Use
1999

■	0
■	Corn
■	DCSW
■	Pasture
■	Wheat
■	Soybean
■	Forest
■	Urban
■	Water

2000 Landuse Polygon Classification

Land Use
2000
- ■ 0
- ■ Corn
- ■ DCSW
- ■ Pasture
- ■ Wheat
- ■ Soybean
- ■ Forest
- ■ Urban
- ■ Water

2001 Landuse Polygon Classification

Land Use
2001
- 0
- Corn
- DCSW
- Pasture
- Wheat
- Soybean
- Forest
- Urban
- Water

2002 Landuse Polygon Classification

Land Use
2002
- 0
- Corn
- DCSW
- Pasture
- Wheat
- Soybean
- Forest
- Urban
- Water

2003 Landuse Polygon Classification
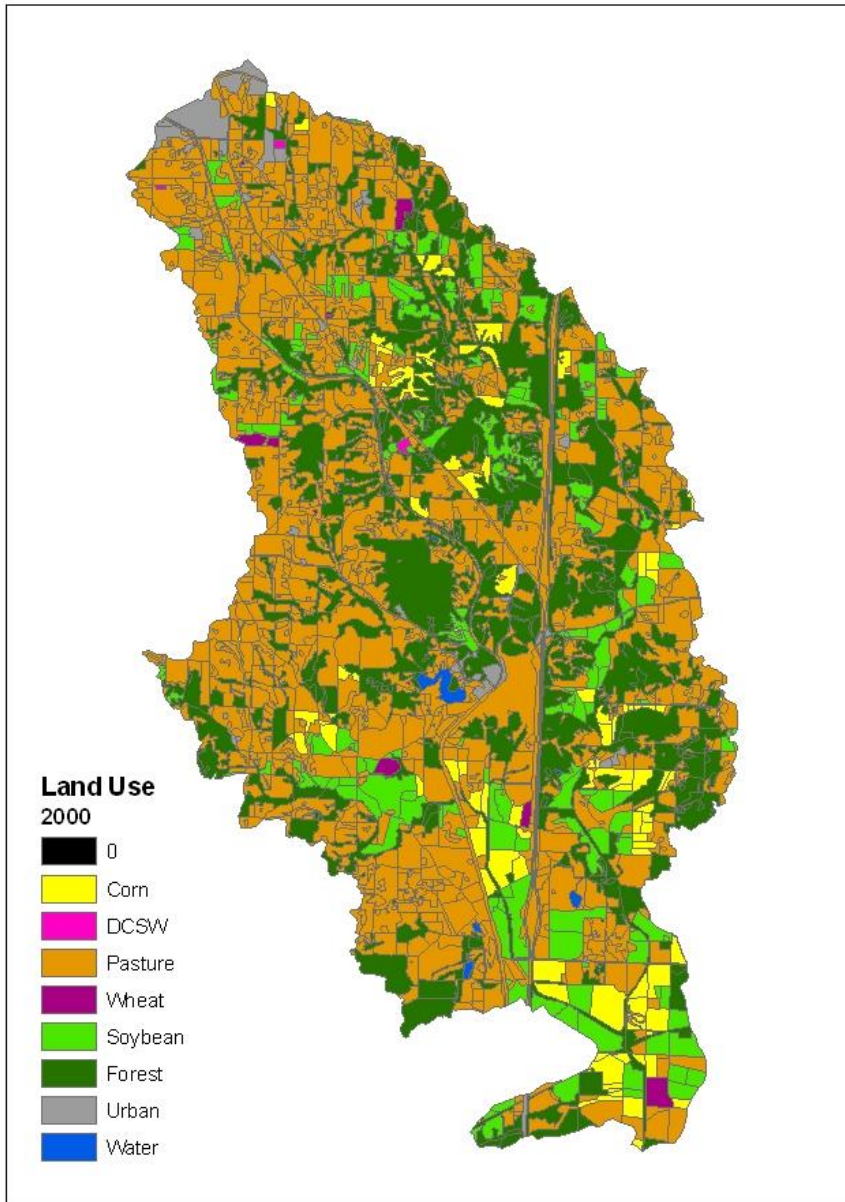
Land Use
2003
- ■ 0
- ■ Corn
- ■ DCSW
- ■ Pasture
- ■ Wheat
- ■ Soybean
- ■ Forest
- ■ Urban
- ■ Water
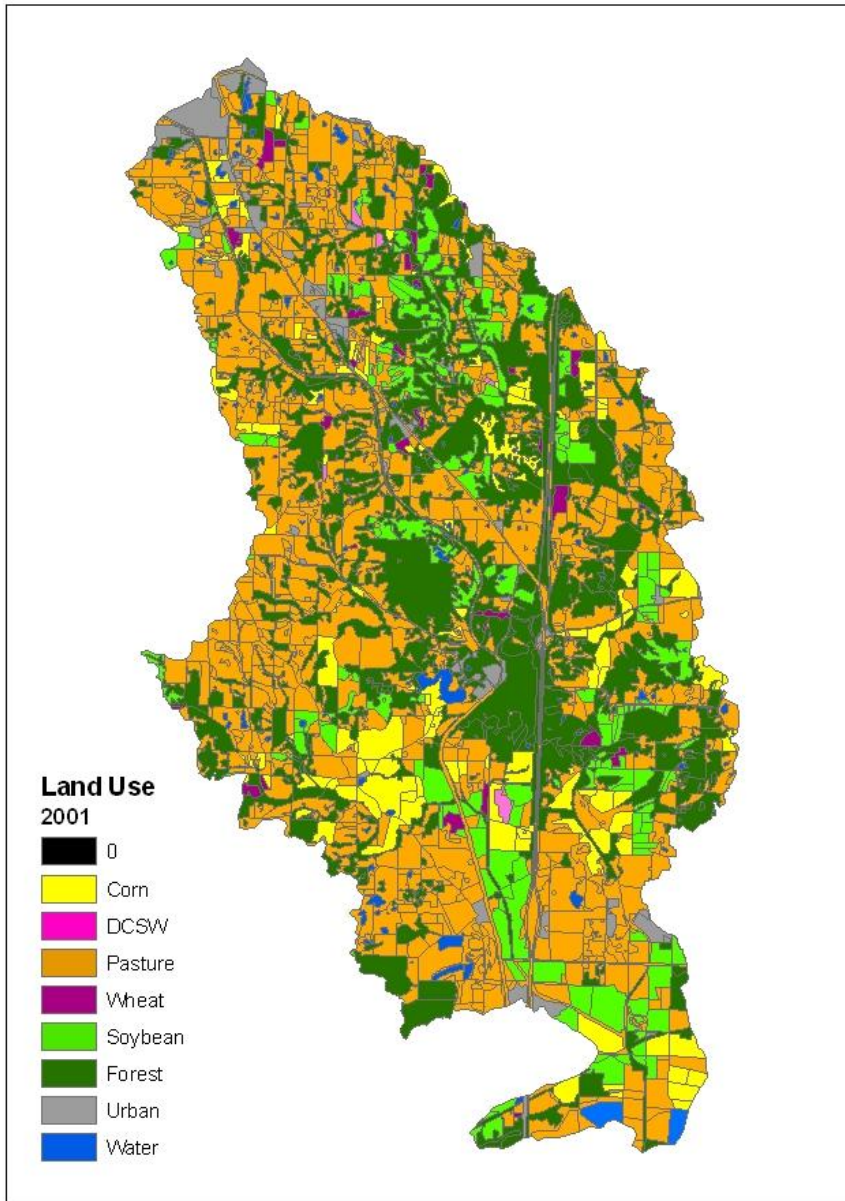
2004 Landuse Polygon Classification
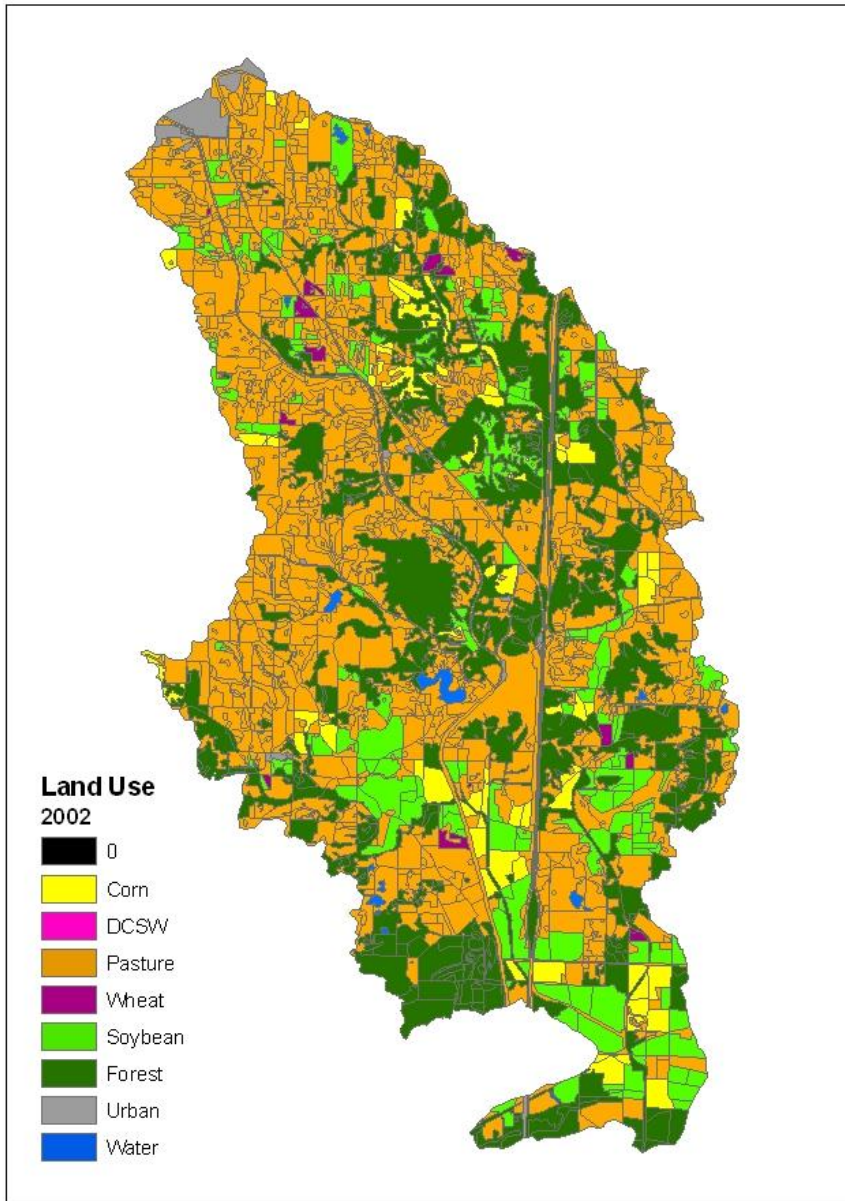
Land Use
2004
- 0
- Corn
- DCSW
- Pasture
- Wheat
- Soybean
- Forest
- Urban
- Water
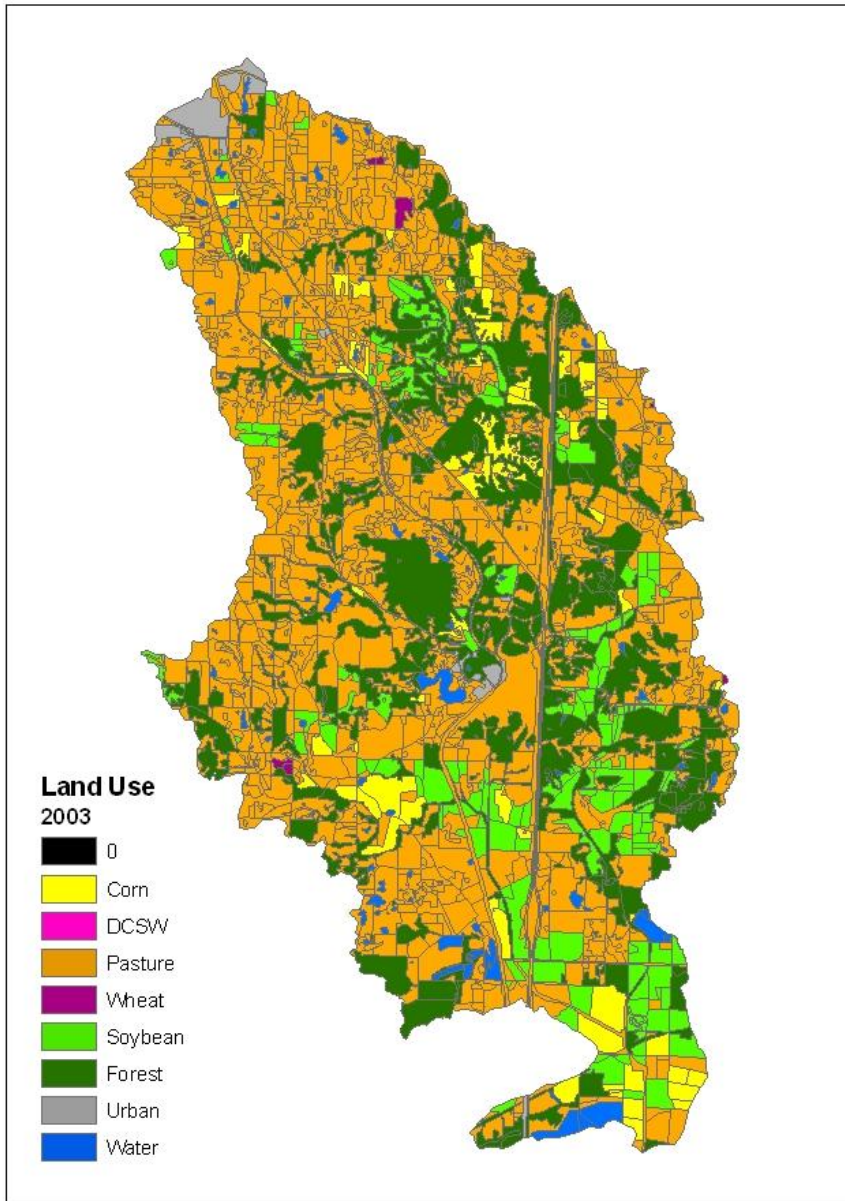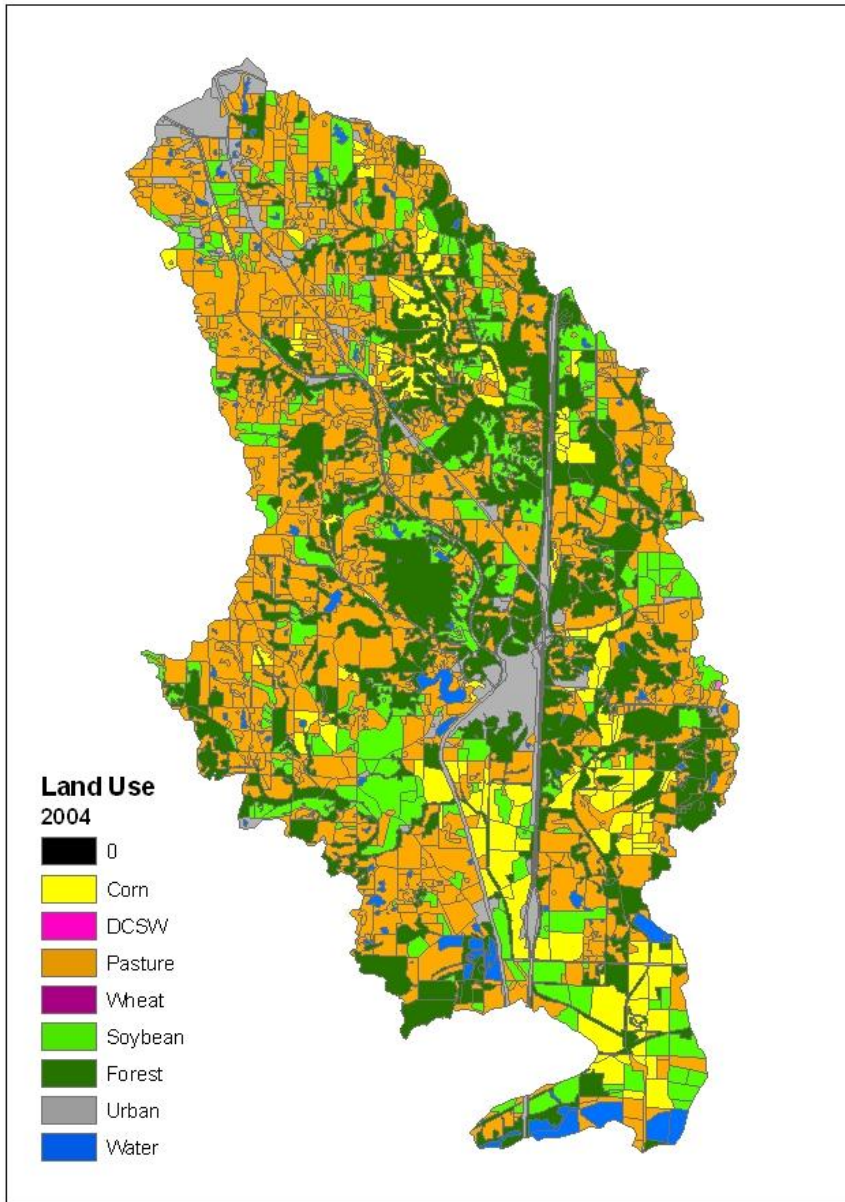
Contingent probabilities of land use in a field given land uses in the previous year

Probability that a hectare will contain

Use last Year	Corn	Soy	Double	Grass	Forest	Total
All Corn	.07	.81	.01	.11	.00	1.00
All Soybeans	.48	.34	.01	.17	.00	1.00
Double Crop	.03	.24	.02	.72	.00	1.00
Pasture/Hay	.02	.07	.01	.89	.00	1.00
Forest	.00	.00	.00	.00	1.00	1.00

Land Use Change Hypotheses

(1) The use chosen for a field is influenced by the *physical geographic* characteristics of the field such as soil type and slope. (Yes)

(2) The use chosen for a field is influenced by *economic* costs and opportunities for various uses. (Yes)

(3) The use chosen for a field is influenced by the *historical* use of that field. (Yes)

(4) The use chosen for a field is influenced by the use of *neighboring fields*. (No)

Corn
Woods
Hay
Pasture
Soybear
Urban

Crop Index

800.000
700.000
600.000
500.000
400.000
300.000
200.000
100.000
0.000

0.157 0.166 0.136 0.181 0.197 0.278 0.295 0.321 0.360 0.377 0.460 0.419 0.573 0.597 0.944 0.965 1.000

Ecosystem Service Index

GA Logic

**Multiple Generations
lead to
Optimal Solution**
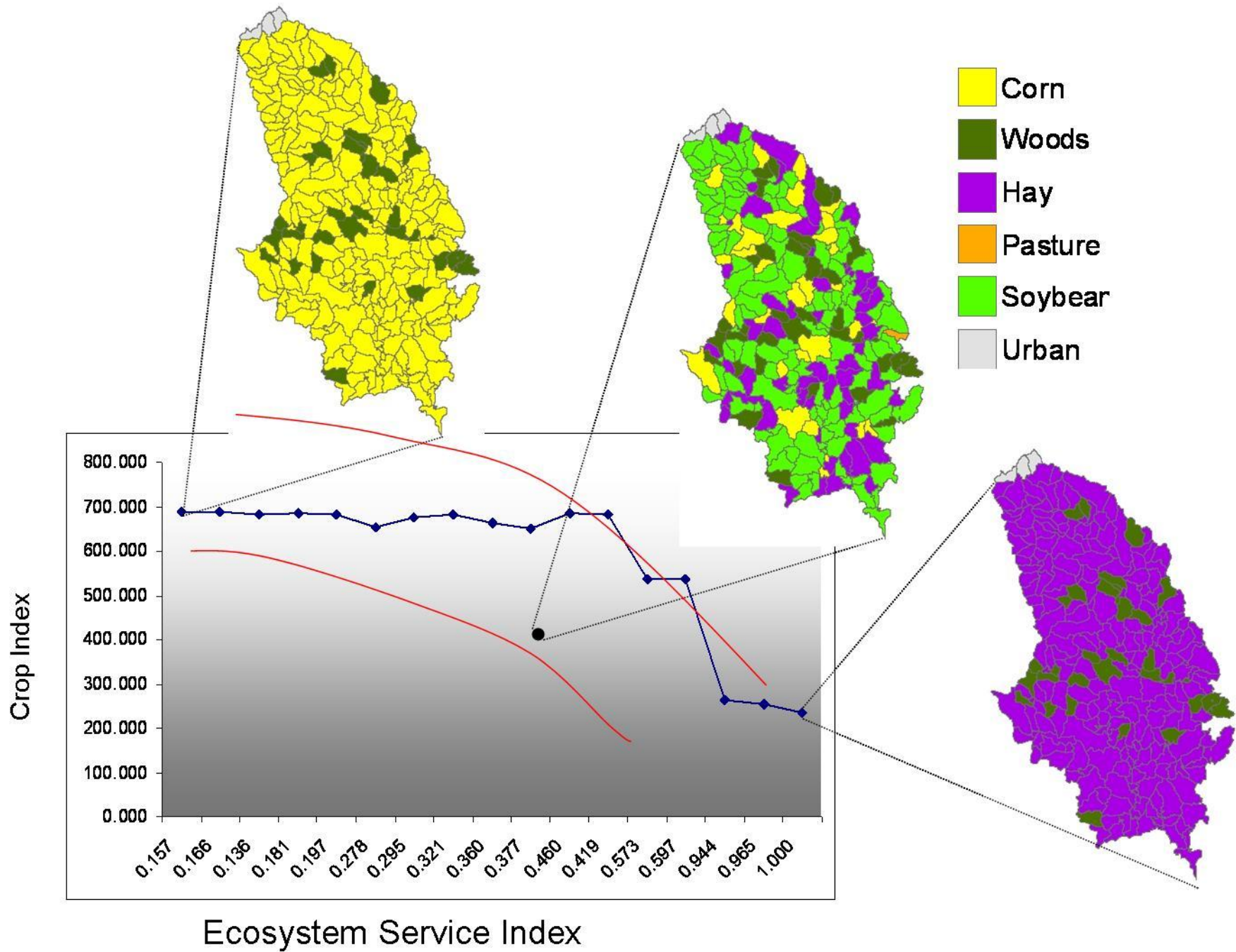
Create sets of Initial Alternatives
(Initial Population)

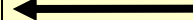Evaluate fitness, Rank the alternatives

Choose mates(pairing)

Create offspring (crossover)

Mutate

Repeat

Optimal Solution

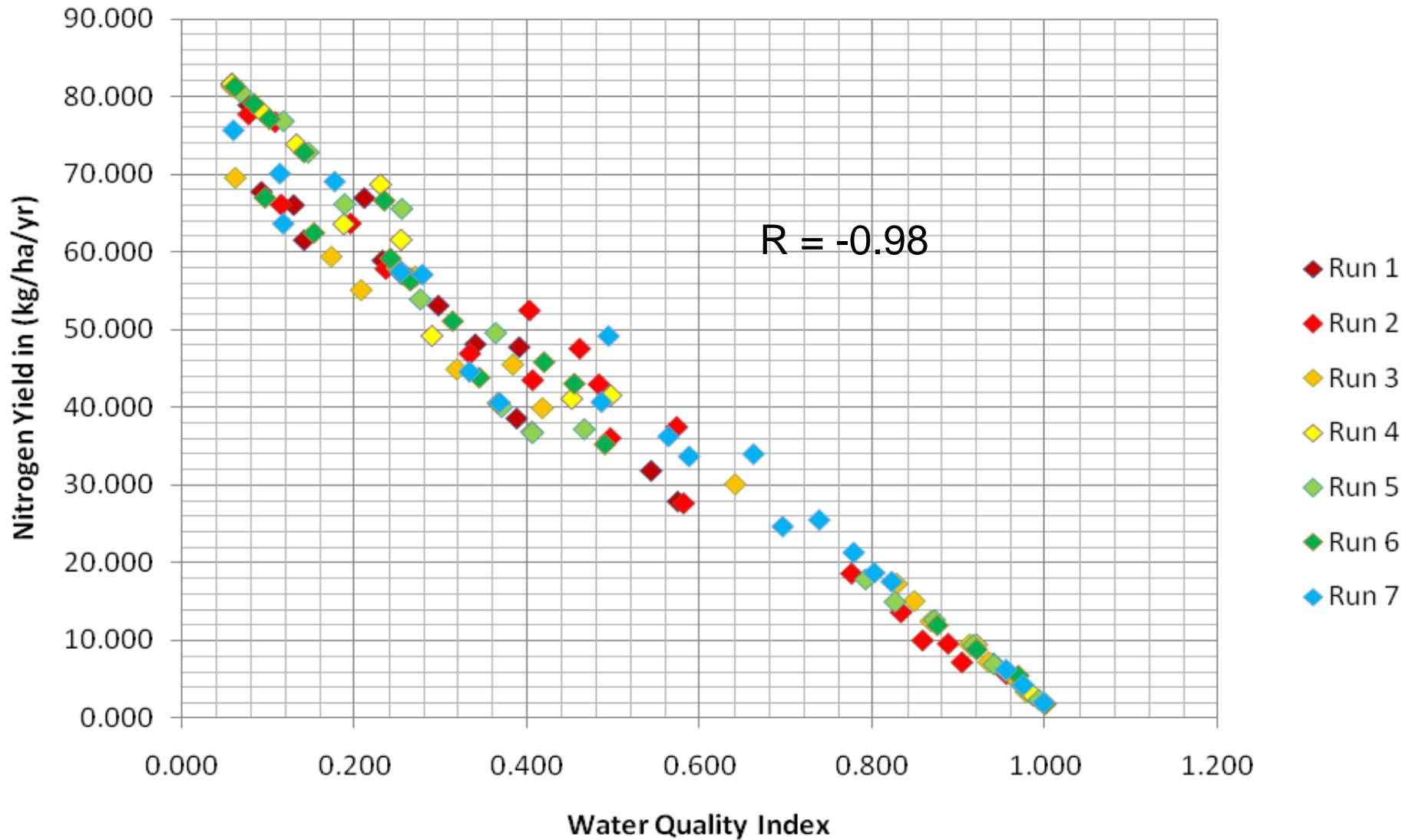# Sediment and Water Quality Index: Highly Correlated
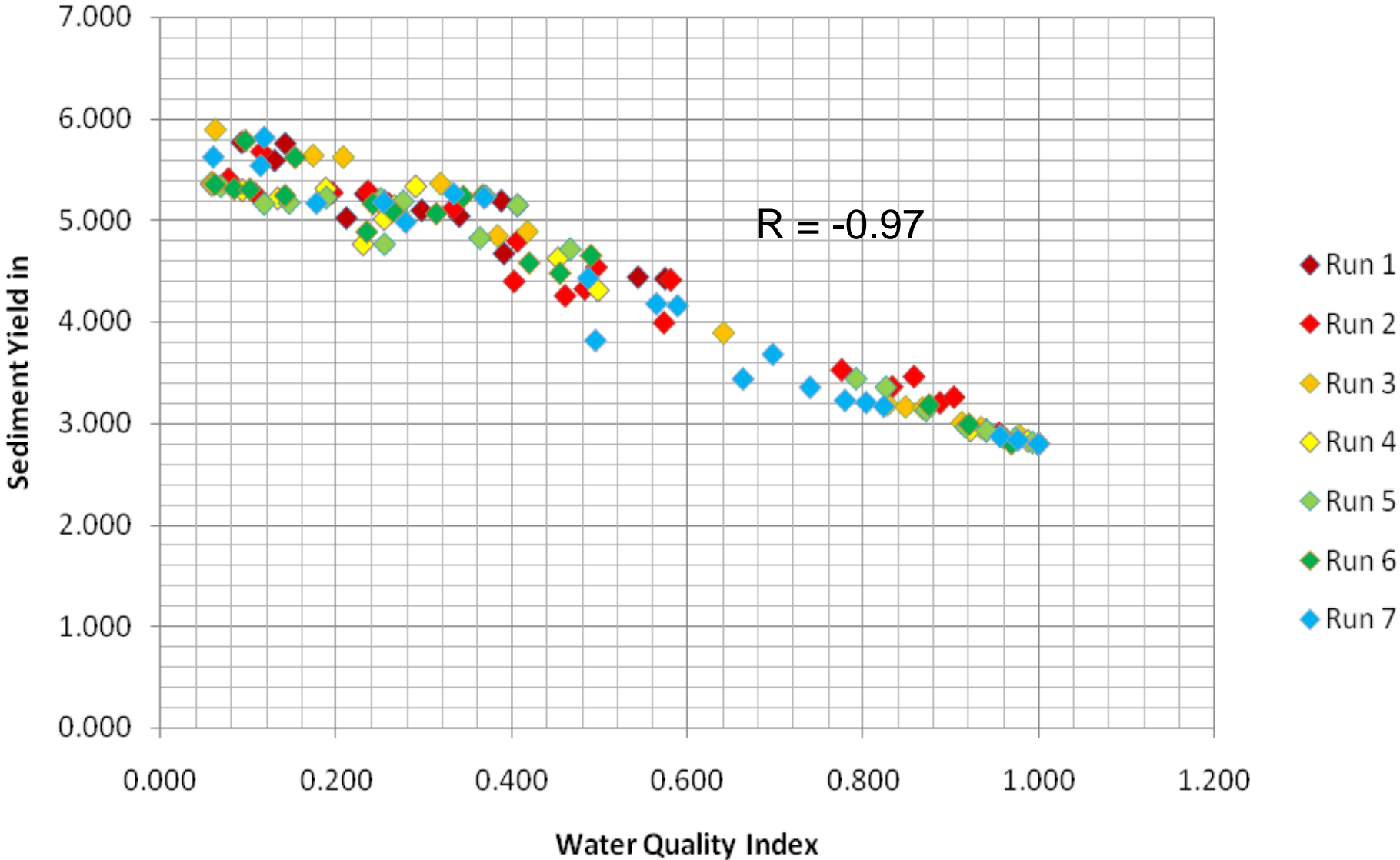
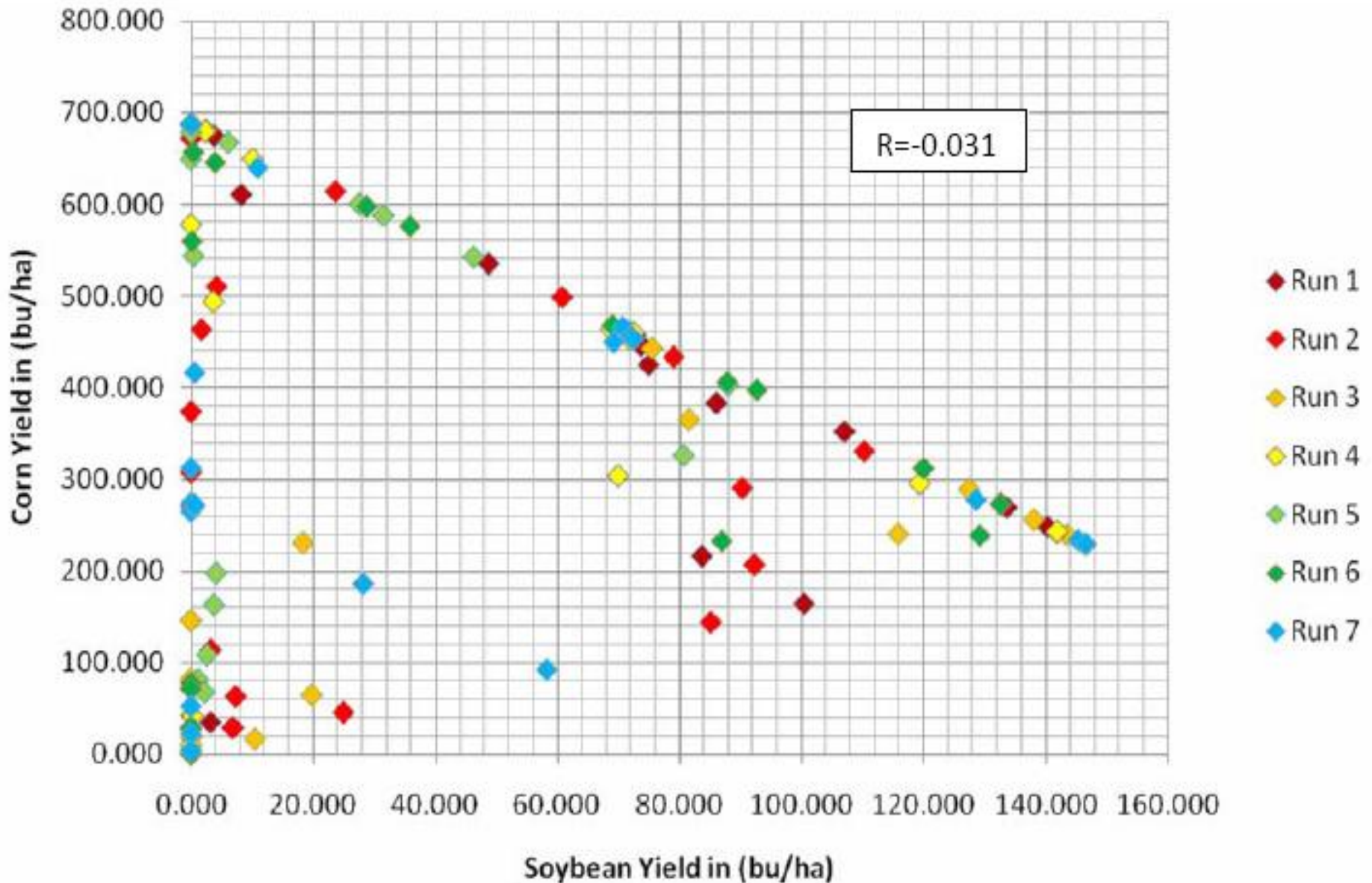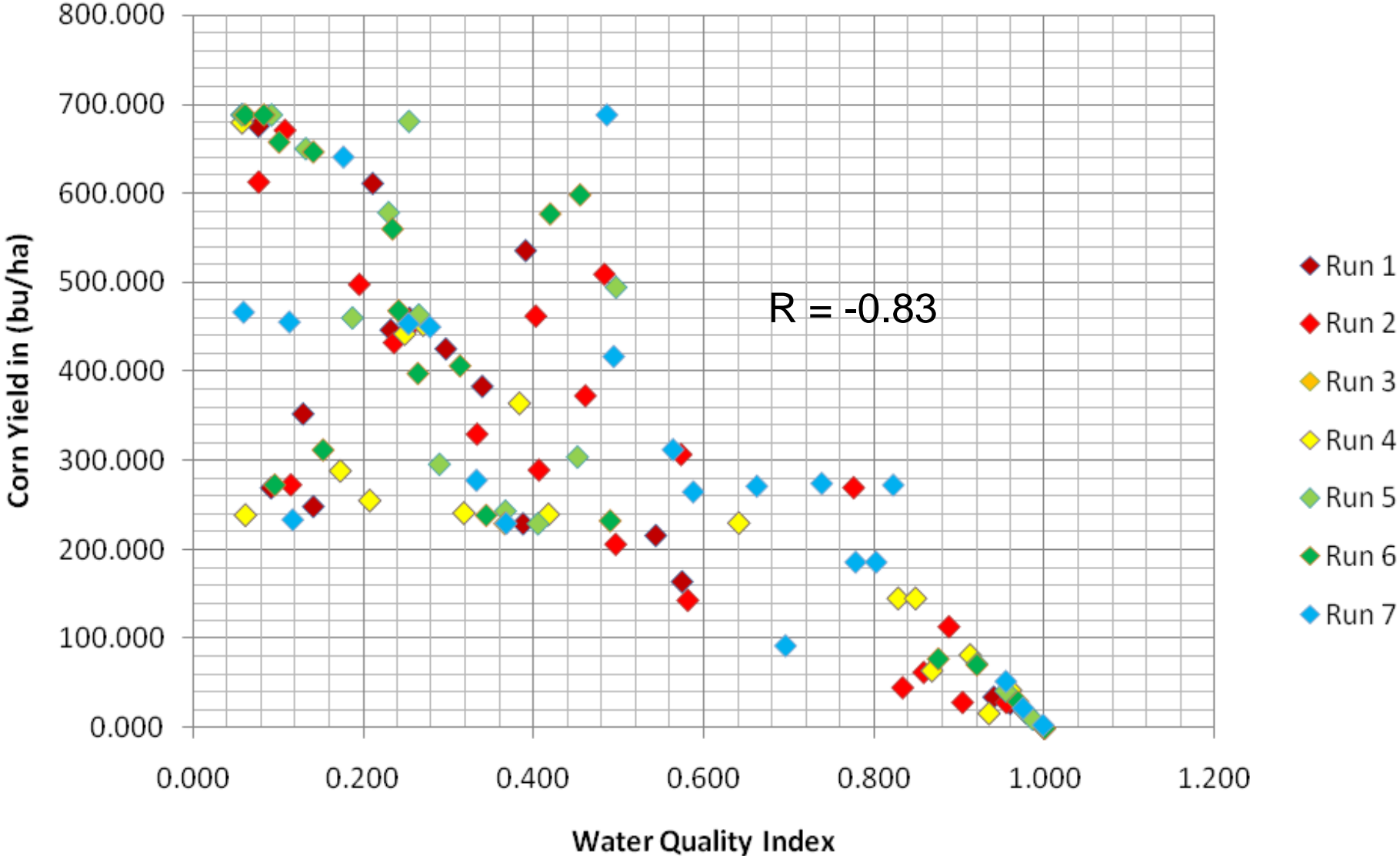# Phosphorus and Water Quality Index: Highly Correlated
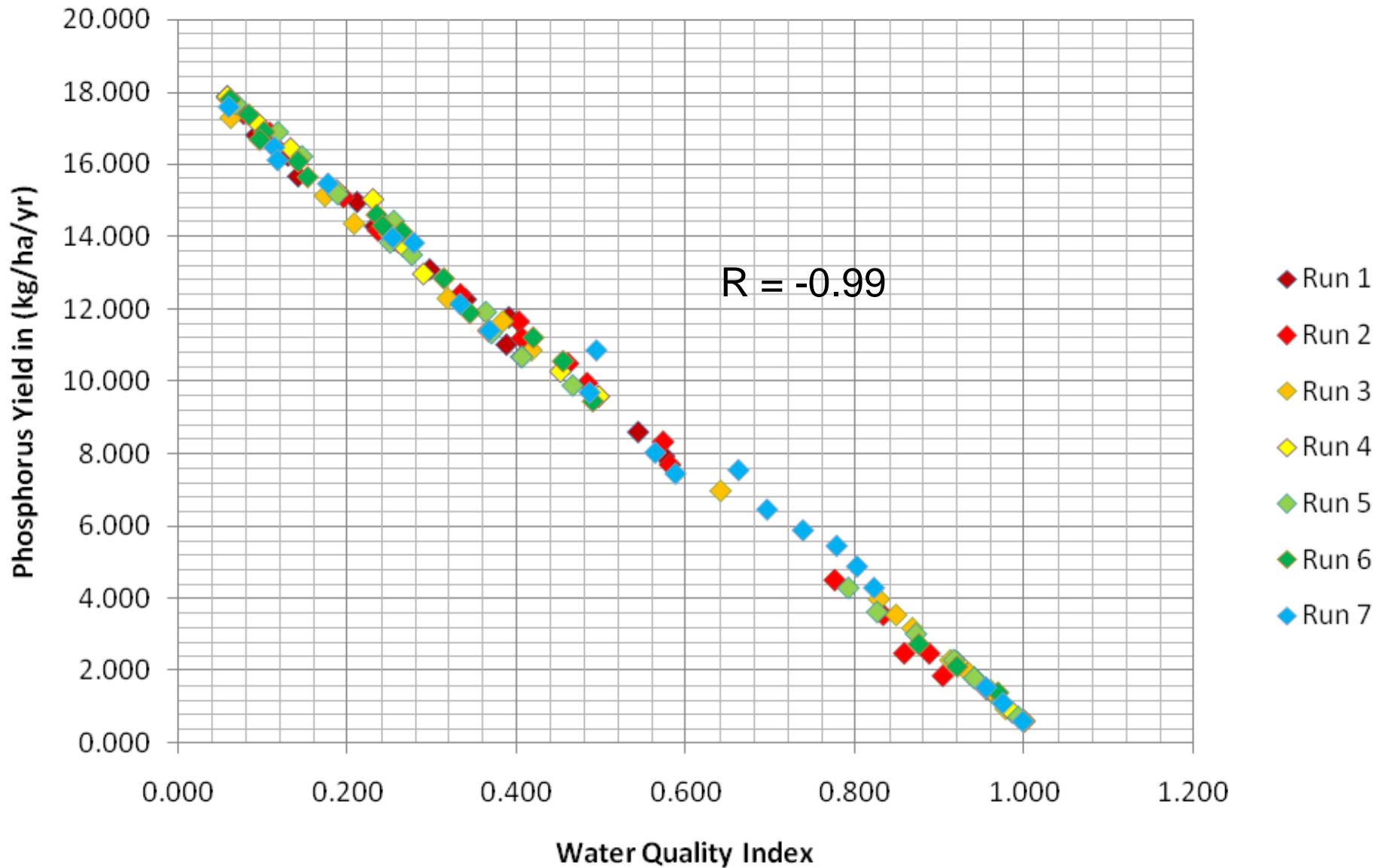
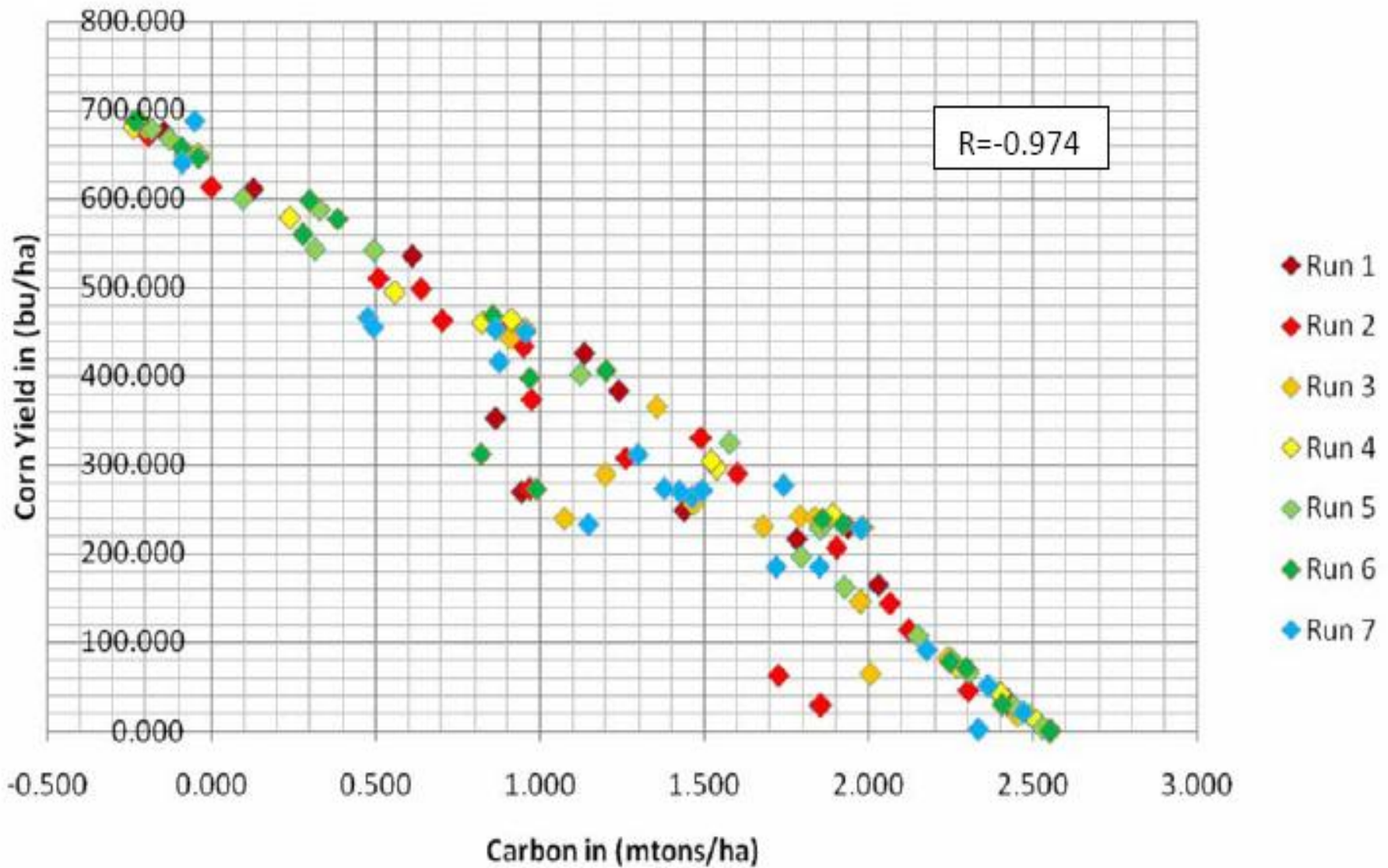**Nitrogen and Water Quality Index: Highly Correlated**
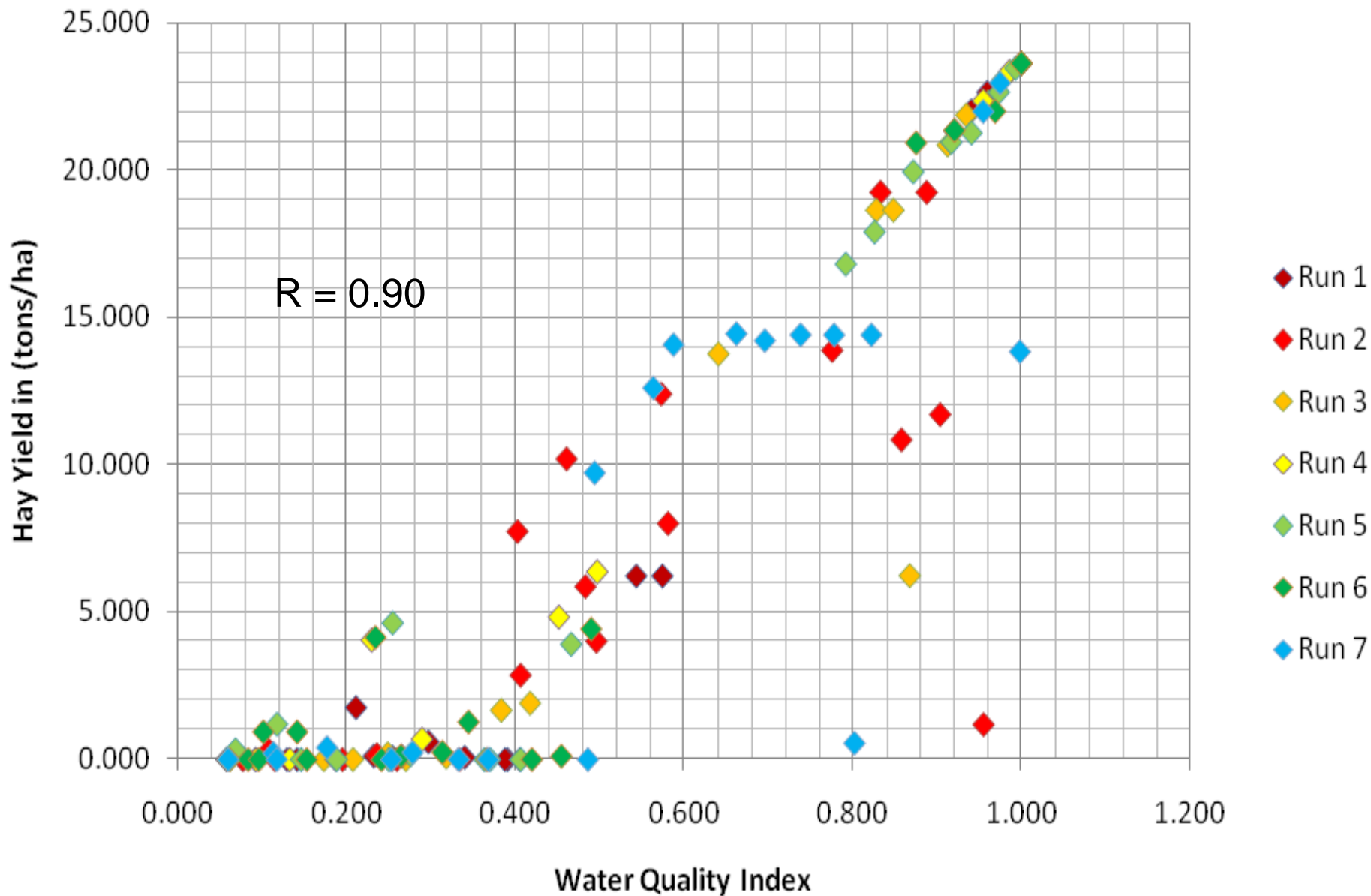
Corn vs. Soybeans: A Classic Trade-off

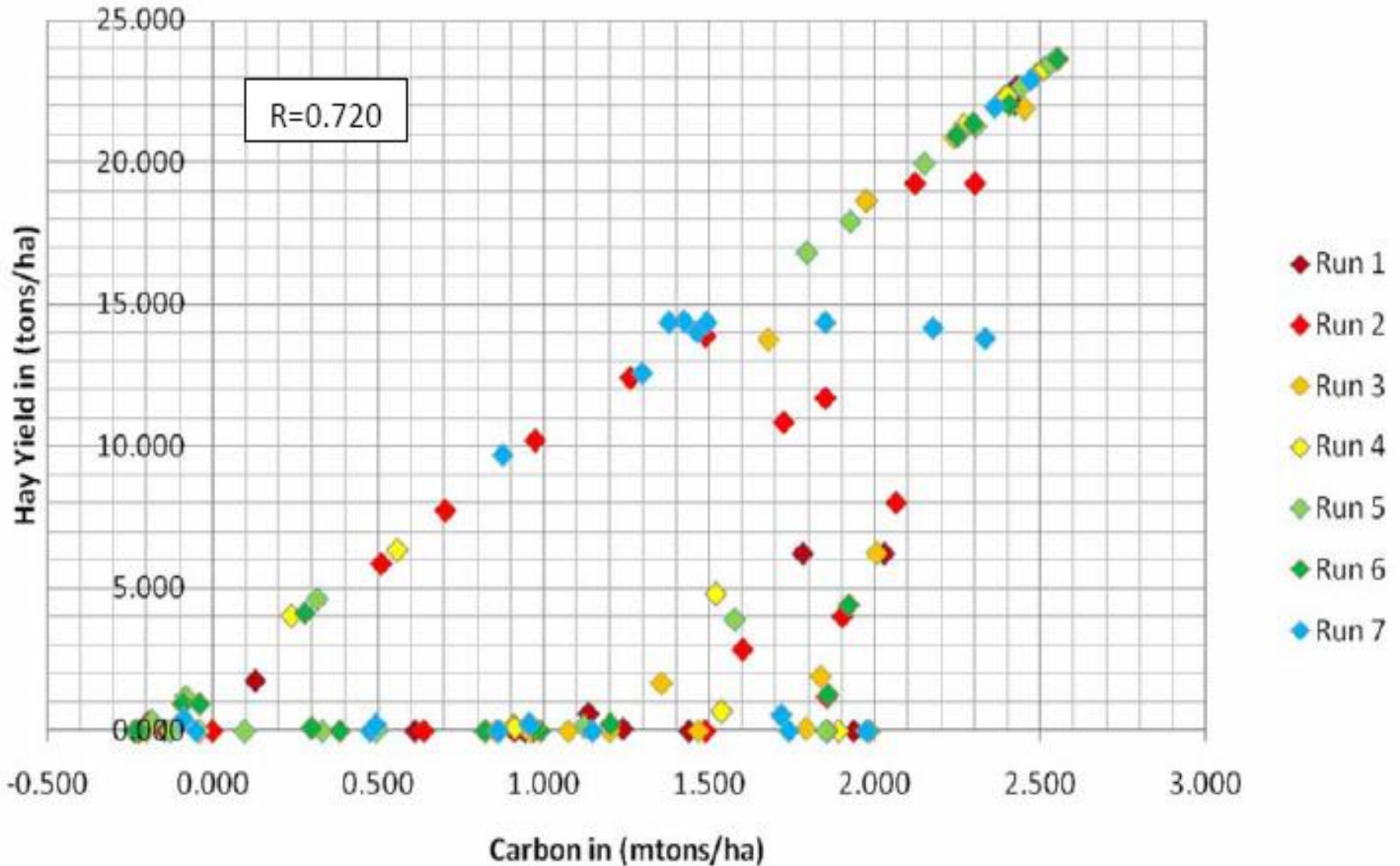# Corn and Water Quality: A Trade-Off

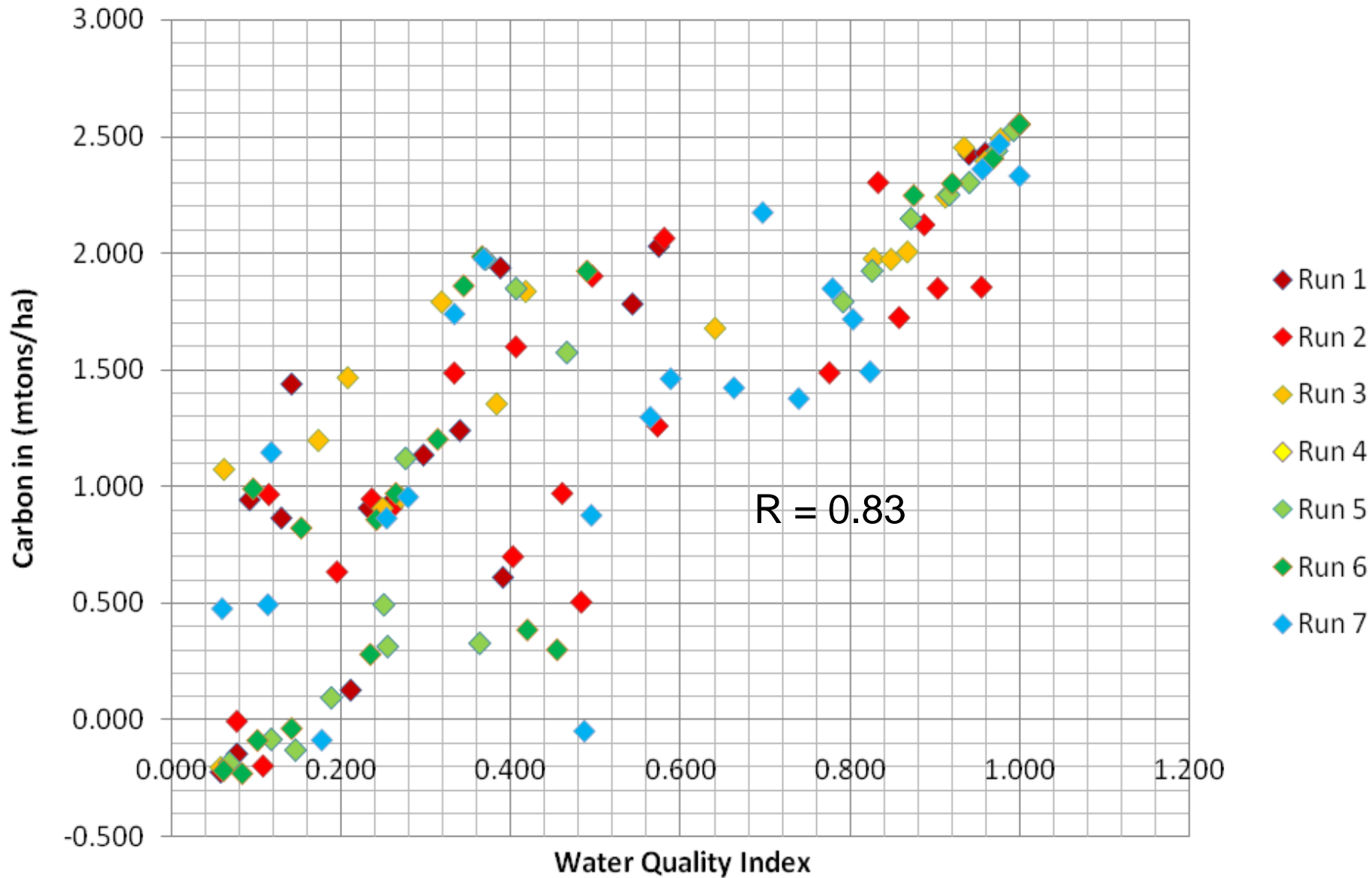# Carbon and Corn: A Trade-Off

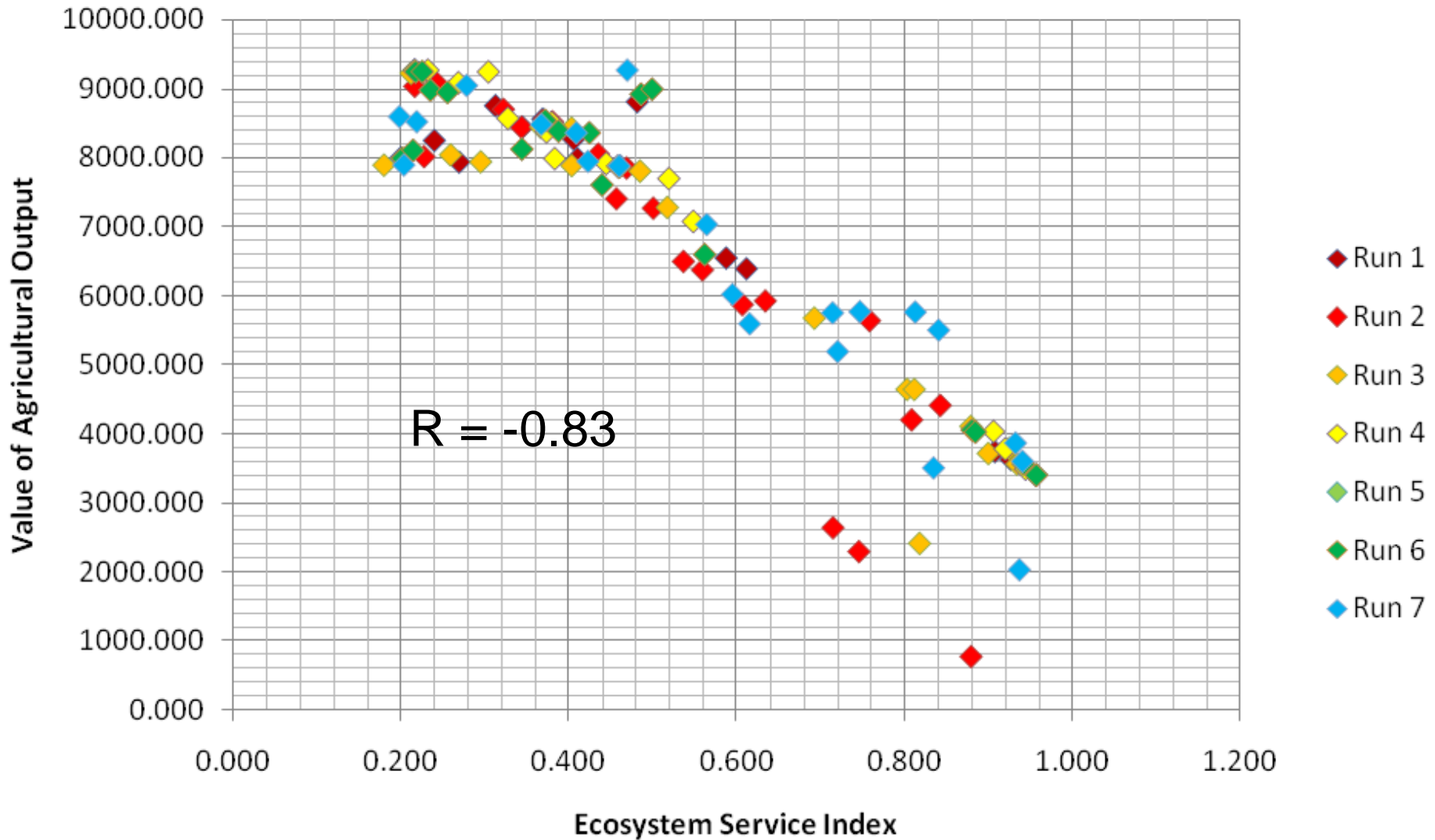**Hay and Water Quality: Complementary**

Carbon and Hay: Complementary

Carbon and Water Quality: Complementary


R = 0.83

The Overall Ecological-Economic PPF

What We've Learned About the PPF

1) Landscapes that yield high or low sediment yields also yield corresponding N and P yields with correlations of 0.93 - 0.98.

2) Competition among crops for land produces as classic PPF

3) Soybeans, and especially corn, is a trade-off with all ecosystem services, but hay is complementary.

4) Carbon correlates positively with water quality at 0.84.

5) The current land use pattern is very sub-optimal, more so with respect to ecosystem services than gross margin.

Users Working with the PPF
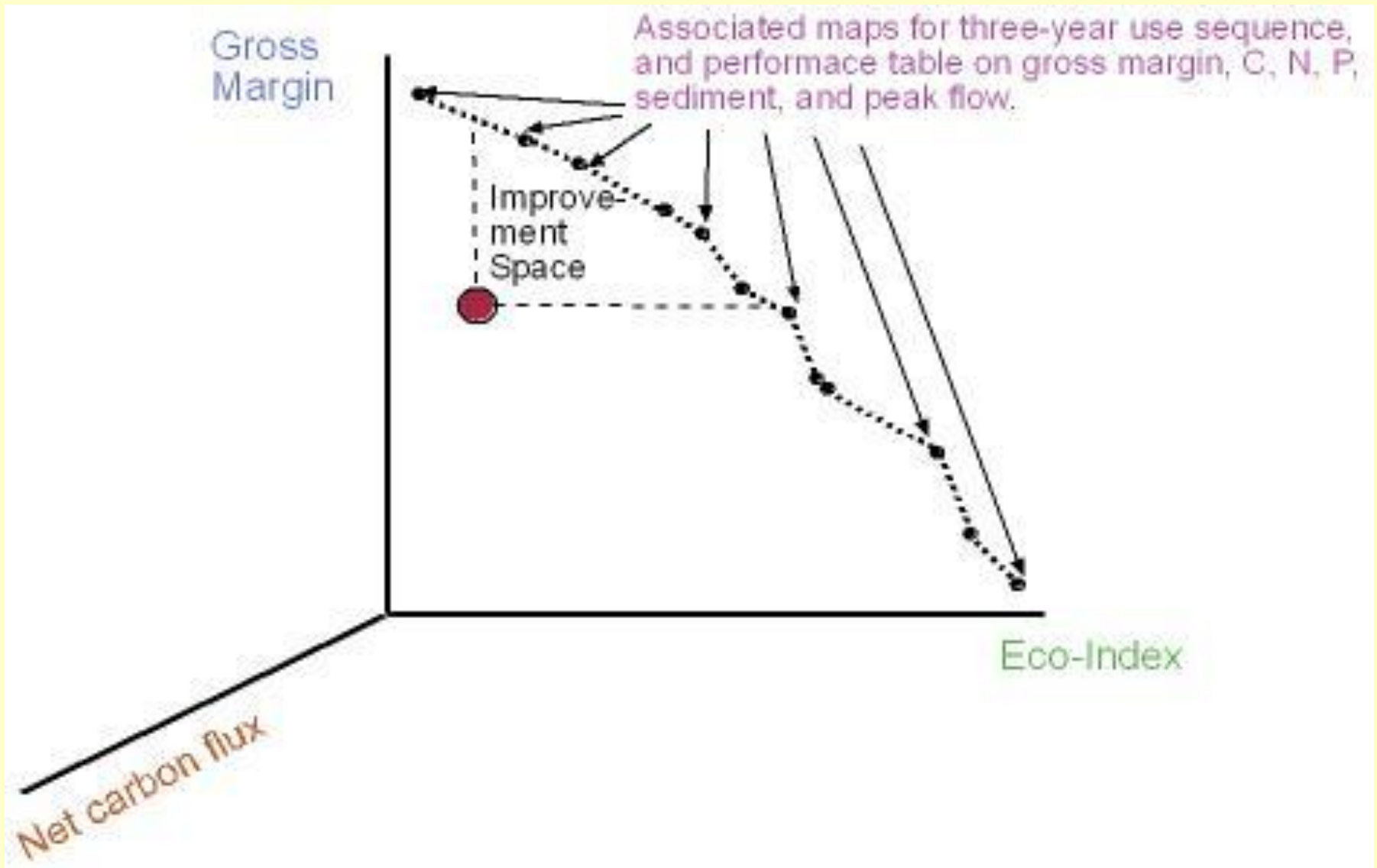
Users Working with the PPF
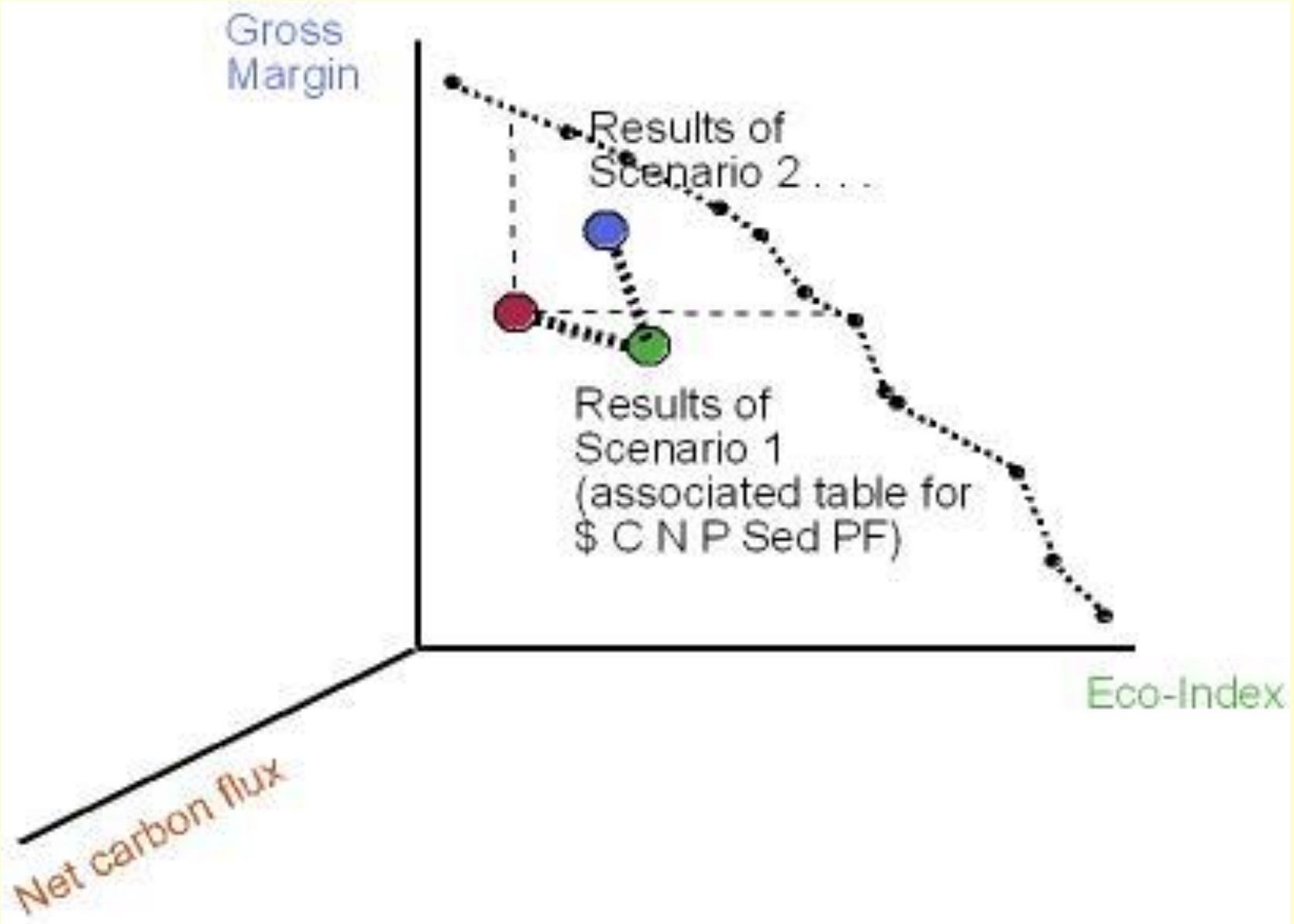
USDA Land Resource Regions

Climate Change, Hydrology and Landscapes of America's Heartland

NSF Coupled Natural and Human Systems PI- Lant co-PI Schoof, Secchi Misgna, Nicklow

Lower Souris

Northern Great Plains

Northern Lake States

Wolf

North Raccoon

Central Feed Grains

Middle Arkansas Lake Mckinney

Bull Shoals Lake

Big Creek

East and Central Farming

Central Great Plains

Upper Yazoo

Bayou Pierre

South Atlantic and Gulf

Mississippi Delta

Modeling Framework with Climate Change