PURDUE UNIVERSITY

PURDUE AGRICULTURE

Data Needs and Empirical Difficulties for Economic Analysis

Wallace E. Tyner

September 22, 2015

Research Questions

- Under which conditions do cover crops provide the greatest benefits?
  - Crop rotations
  - Soil class
  - Tillage
  - Residue removal
- How much corn residue can be sustainably removed with and without cover crops?

What We Don’t Know

- There are many claimed benefits for improved soil health and cover crops:
  - Reduced soil erosion
  - Increased soil organic carbon
  - Reduced nitrate leaching
  - Increased water retention capacity
  - And many others
- We have a pretty good idea of the technical soil impacts for many of these cases.
- We do not know what they are worth.

How Do We Get to Economic Values?

- There are projects in place that are using strip trials to try to estimate physical and economic impacts of different cultivation practices and cover crops.
- We need to continue these and move them closer to estimating economic impacts (e.g., SHP).
- However, we also need to get better economic estimates of the different categories of benefits such as soil erosion.
- We also need data and analysis on farmer fields and measures of economic impacts (e.g., yields and costs) that matter to farmers.
- We can also use models to help estimate economic values.

Impact Area Economic Values

Author	Year	Indicator	Site	Value	Units
USDA	2014	Soil Erosion	On-Site	10.17	$/ton
USDA	2014	Soil Erosion	Off-Site	17.99	$/ton
Hansen & Ribaudo	2008	Soil Erosion	On-Site	1.01	$/ton
Hansen & Ribaudo	2008	Soil Erosion	Off-Site	2.77	$/ton
Lal	2014	Soil Organic Carbon	On-Site	0.06	$/lb.
Christianson et al.	2013	Denitrification	On-Site	0.95	$/lb.
Methanol Institute	2011	Denitrification	Off-Site	0.6	$/lb.
US EPA	2008	Denitrification	Off-Site	1.5	$/lb.

Value of soil erosion ranges between $3.78/ton and $28.16/ton just from these sources.
Value of denitrification ranges between $0.60/lb. and $1.50/lb.

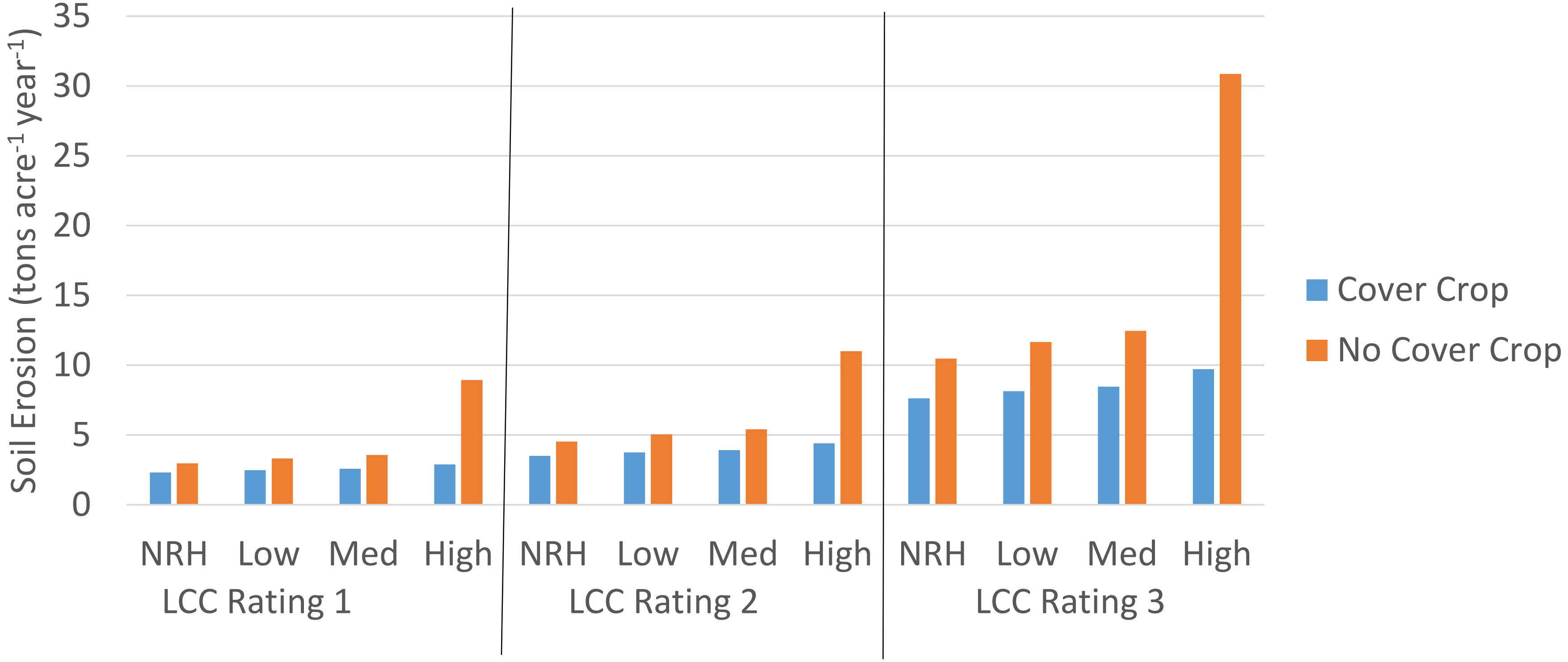
Landscape Environmental Assessment Framework (LEAF)

- Developed by Muth & Bryden (2011)
  - Revised Universal Soil Loss Equation, Version 2 (RUSLE 2)
  - Wind Erosion Prediction System (WEPS)
  - Soil Condition Index (SCI)
  - DeNitrification – DeComposition (DNDC)
- Simulates environmental outcomes from different management practices

LEAF

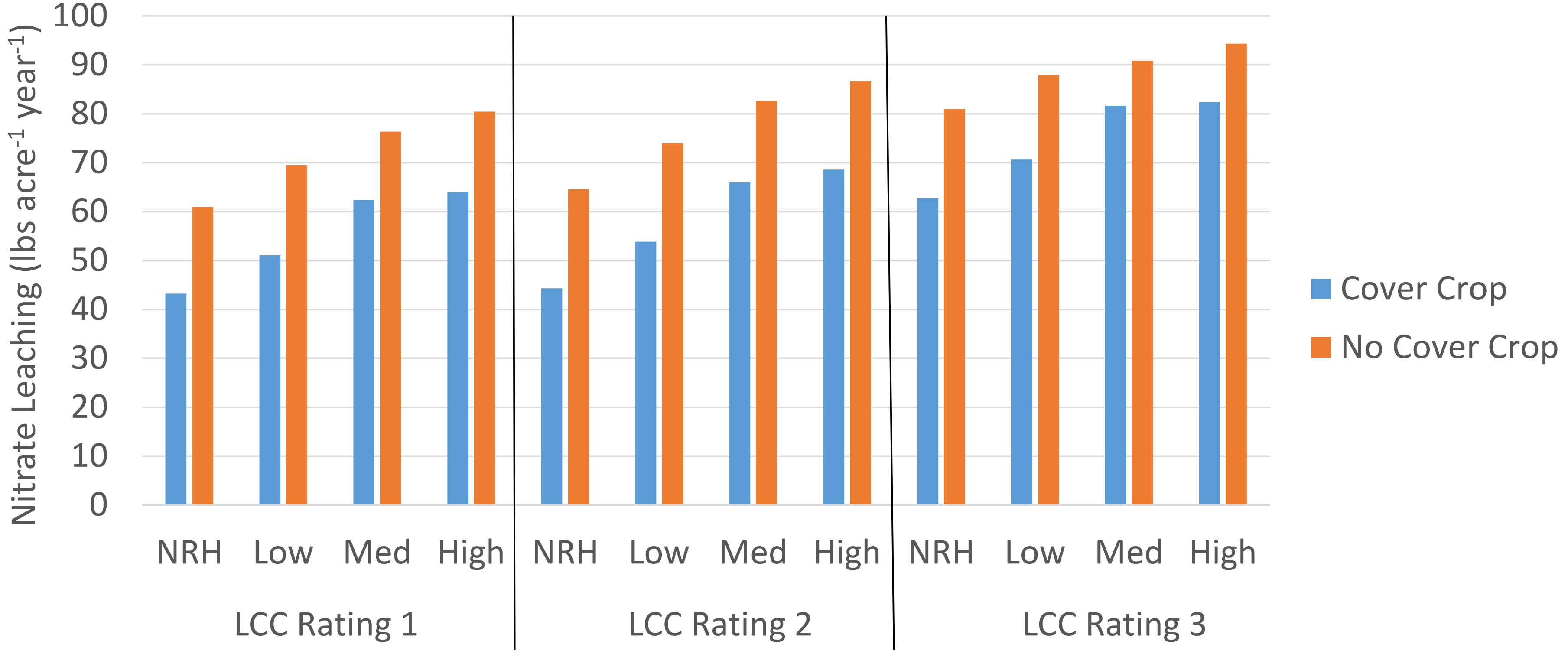
- Geographic region for this study: Indiana
- Management practices: two cover crop options, four residue removal rates, two crop rotations, two tillage practices.
- Each permutation of management practices is run on soil types in SSURGO database.
  - Only soil types with greater than 1000 acres were used

Cover Crops Improve Environmental Outcomes



Soil erosion with and without cover crops for corn soybean rotation and reduced till.

Nitrate Leaching Lower with Cover Crops



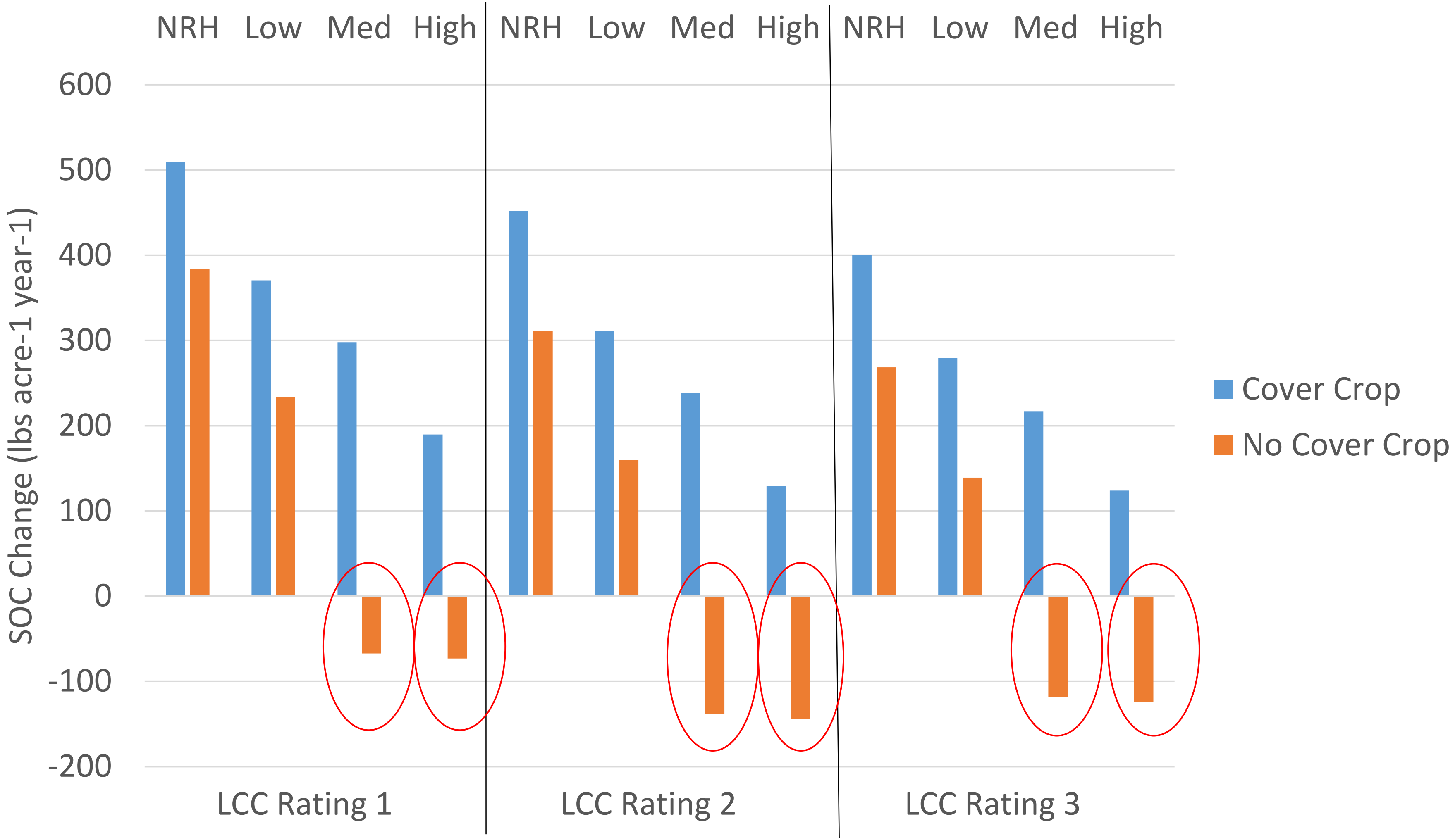
Nitrate leaching with and without cover crops for continuous corn rotation and reduced till.

PURDUE UNIVERSITY

PURDUE AGRICULTURE

Benefits vary by group

- Reduced till benefits more from cover crops than no till.
- Continuous corn rotations benefit more from cover crops than corn soybean rotations.
- Soils with higher LCC rating benefit the most from cover crops.
- Cover crops are usually needed to maintain positive SOC for medium residue harvest and high residue harvest.



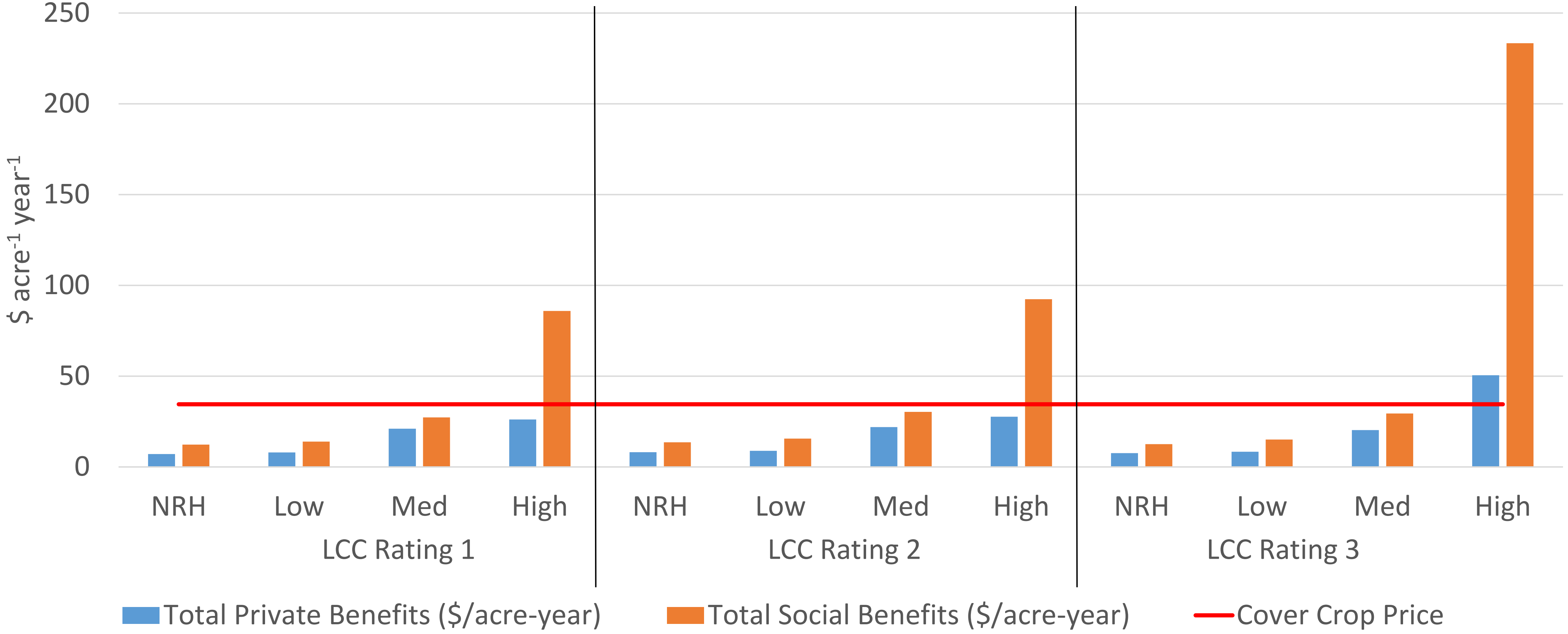
SOC Change for continuous corn no till.

- Considering only the private benefits of reduced soil erosion, reduced nitrate leaching and increased SOC rarely justifies the costs of cover crops. To convince farmers to adopt, we will need better information on economic benefits.

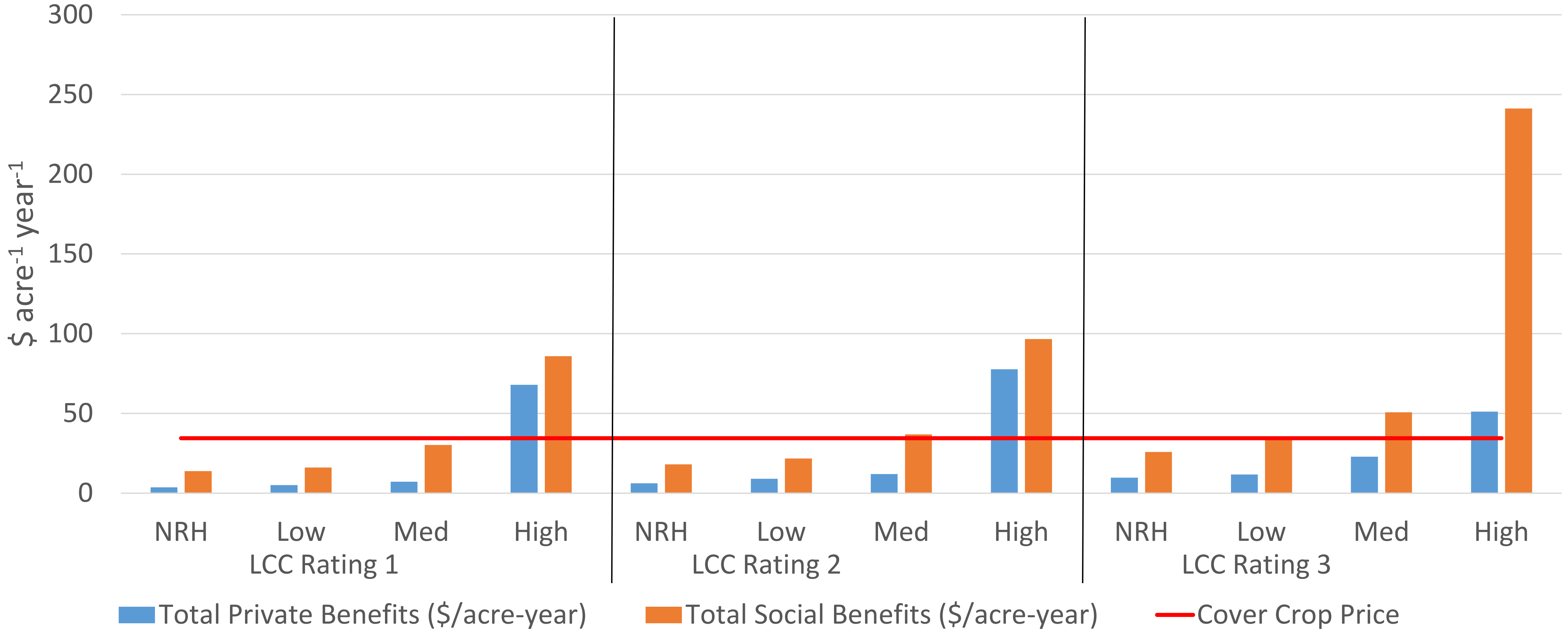
- For high residue harvest, the social benefits of cover crops always exceed the costs.

- Corn silage is a highly erosive crop without cover crops.

Private and social benefits of cover crops. Continuous corn and no till.

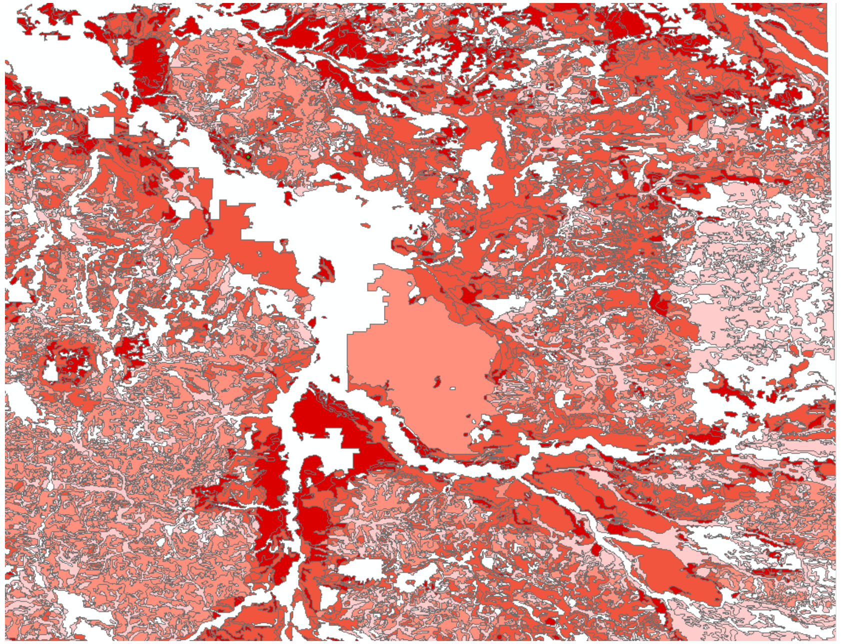


Private and social benefits of cover crop. Continuous corn and reduced till.



SOUTHEAST ELKHART COUNTY, CORN SILAGE-SOYBEANS AND NO-TILL SOIL EROSION

No Cover Crop

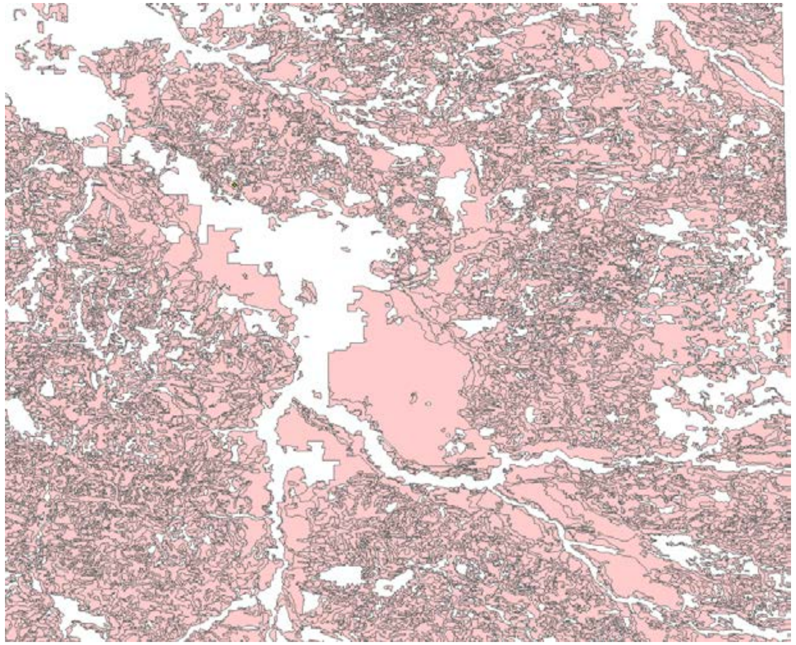


12.05 - 16.14
16.15 - 20.85
20.86 - 53.73
53.74 - 81.88

Tons/Acre/Year

- Positive Average SOC ✗
- Positive SCI ✗
- Erosion < T-Factor ✗

Winter Rye Cover Crop



0.40 - 3.01

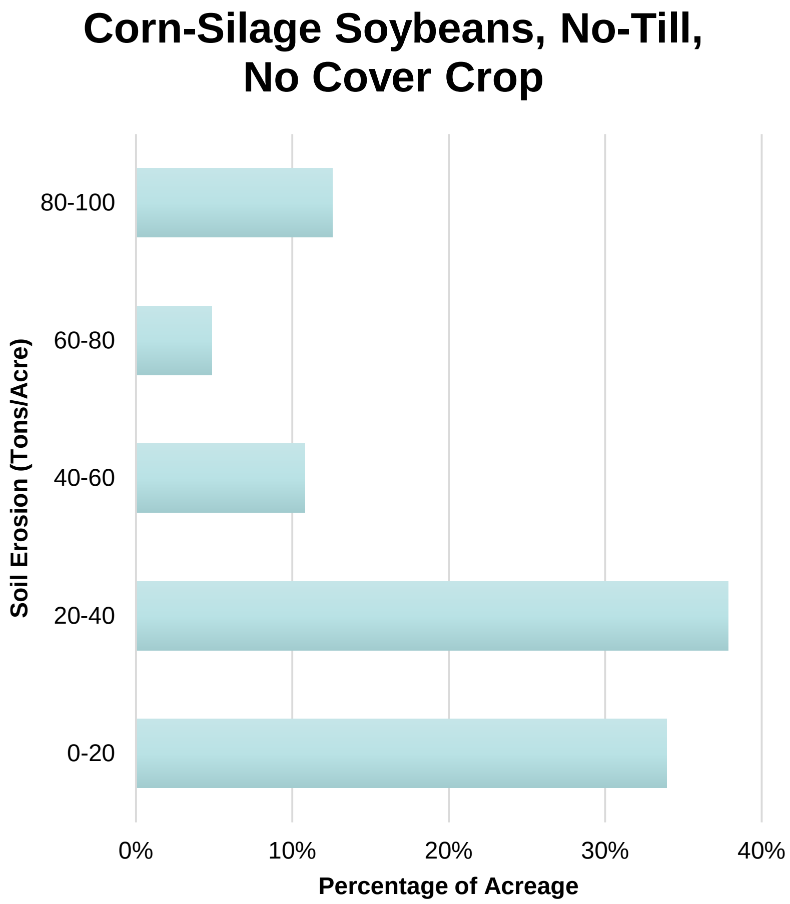
Tons/Acre/Year

- Positive Average SOC ✓
- Positive SCI ✓
- Erosion < T-Factor ✓

CORN SILAGE-SOYBEAN ROTATION, NO-TILL, NO WINTER COVER CROP

Elkhart County, Indiana

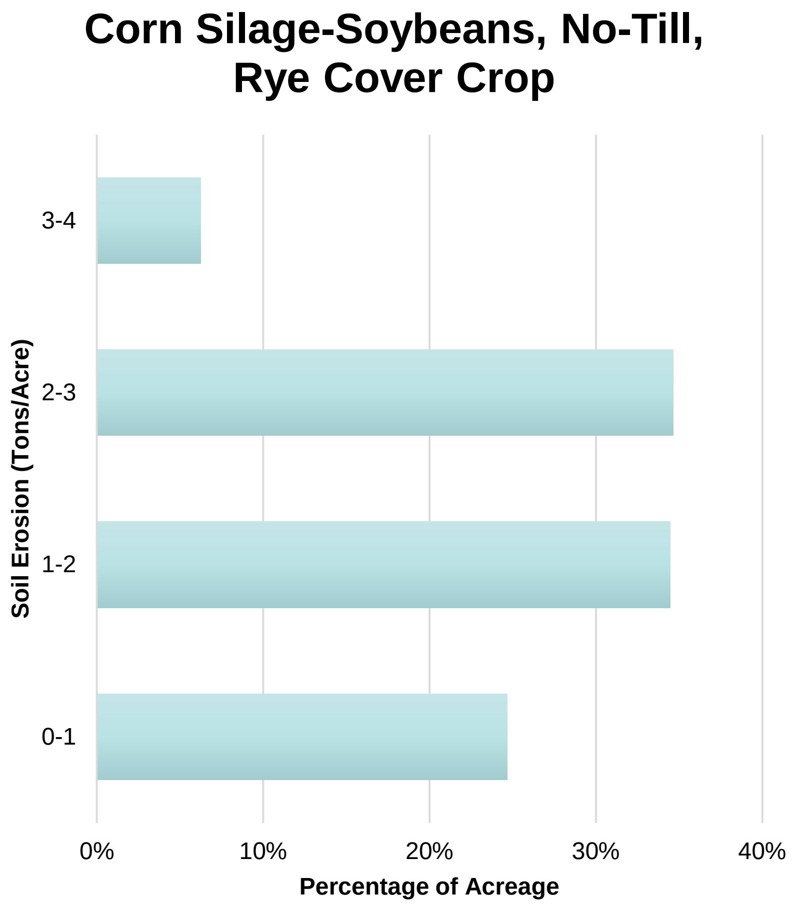
- Average Soil Erosion: 36.12 Tons/Acre/year
- Average Change in Soil Organic Carbon: -44.03 Lbs./Acre/Year
- 0% of Acreage has erosion levels less than their T-Factor, the maximum level of sustainable erosion
- 0% of acreage has positive Soil Conditioning Index (SCI), a qualitative predictor of a management practice's impact on organic matter



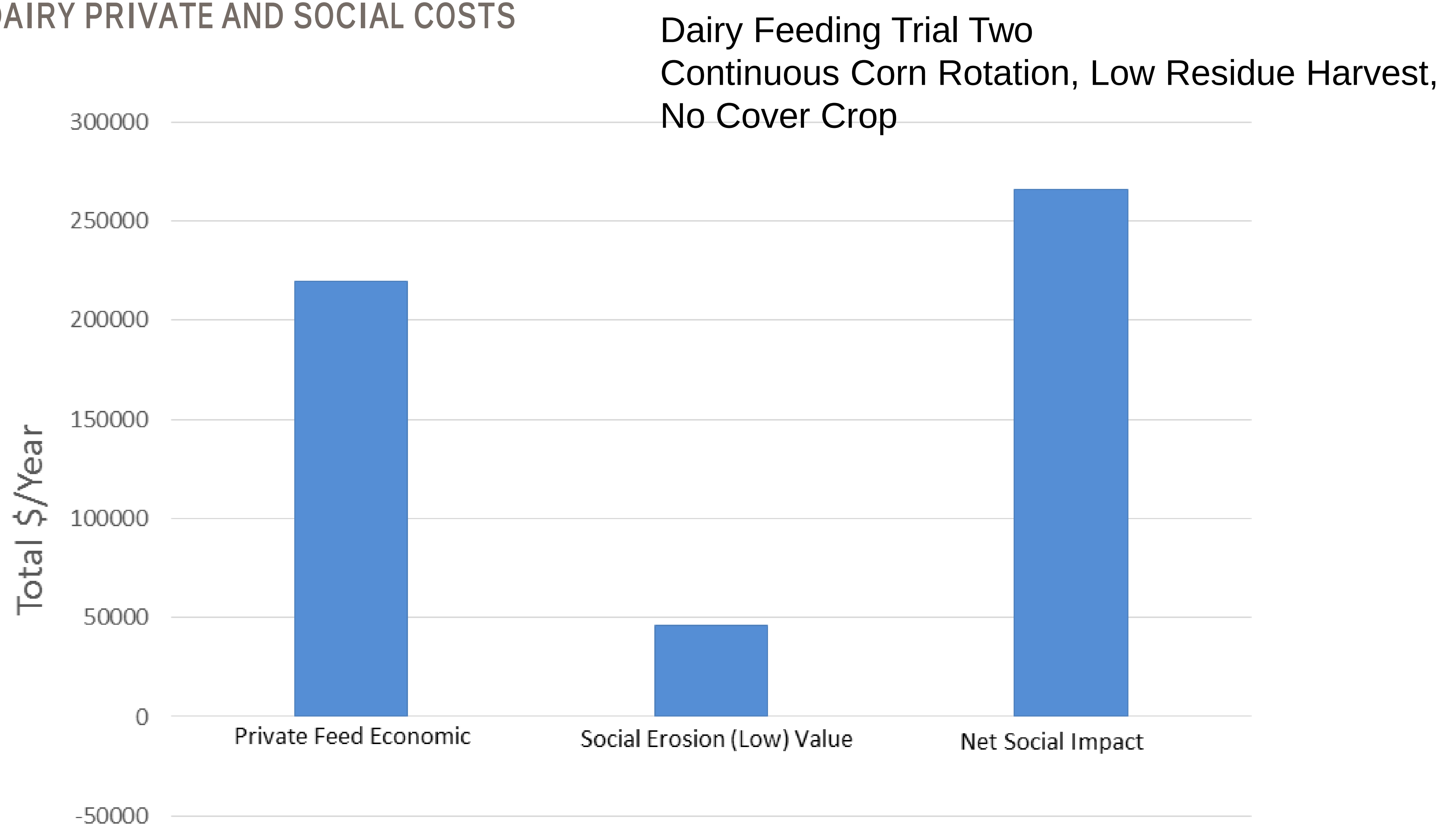
CORN SILAGE-SOYBEAN ROTATION, NO-TILL, WINTER RYE COVER CROP

Elkhart County, Indiana

- Average Soil Erosion: 1.71 Tons/Acre/year
- Average Change in Soil Organic Carbon: 78.92 Lbs./Acre/Year Increase
- 100% of Acreage has erosion levels less than their T-Factor, the maximum level of sustainable erosion
- 100% of acreage has positive Soil Conditioning Index (SCI), a qualitative predictor of a management practice's impact on organic matter



DAIRY PRIVATE AND SOCIAL COSTS



Conclusions

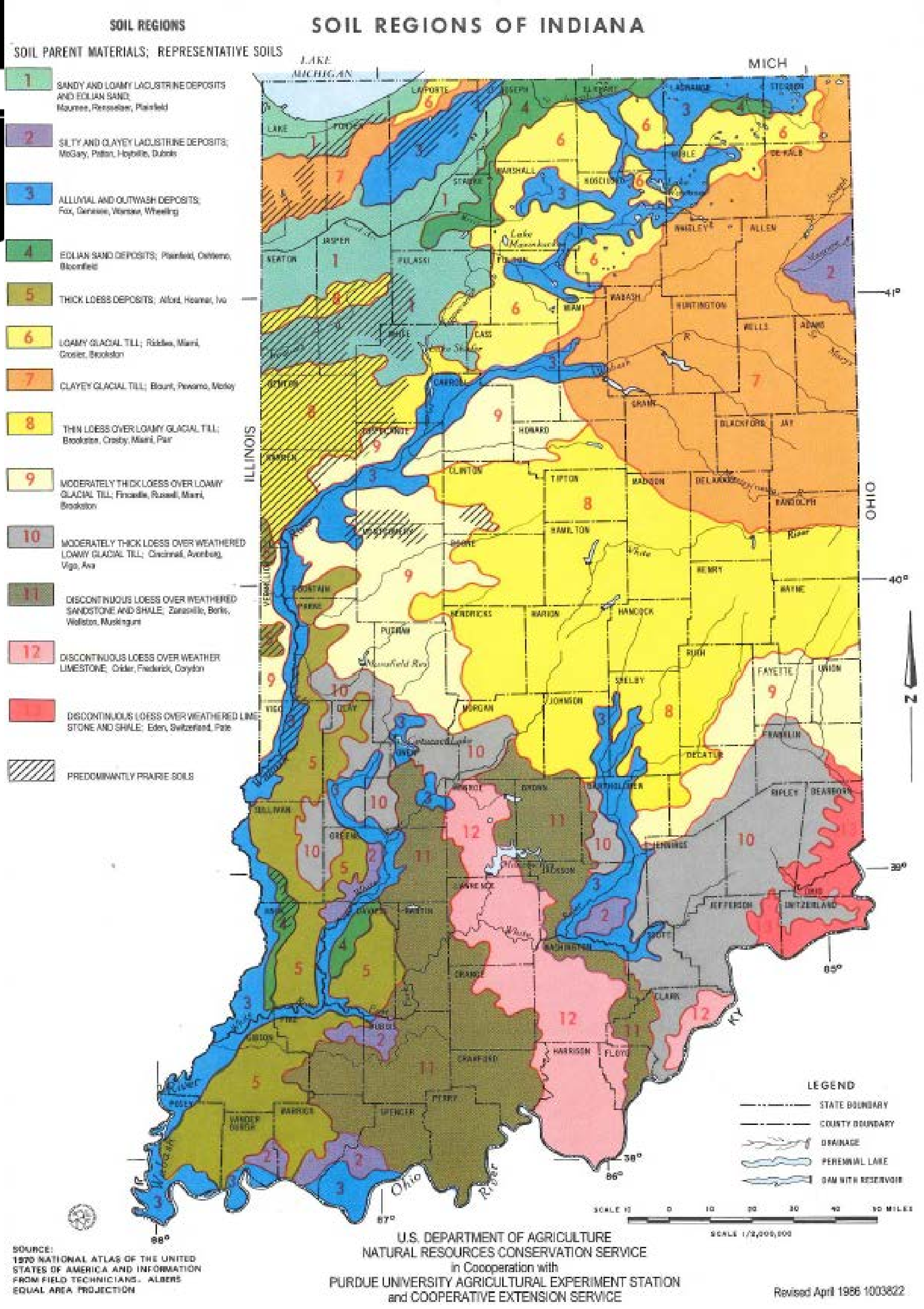
- Cover crops improve environmental outcomes.
- Reduced till benefits more from cover crops than no till.
- Continuous corn rotations benefit more from cover crops than corn soybean rotations.
- Soils with higher LCC rating benefit the most from cover crops.
- Cover crops are usually needed to maintain positive SOC for medium residue harvest and high residue harvest.
- Considering only the private benefits of reduced soil erosion, reduced nitrate leaching and increased SOC rarely justify the cost of cover crops.
- For high residue harvest, the social benefits of cover crops always exceed the costs.
- Cover crops provide huge environmental benefits for corn silage.

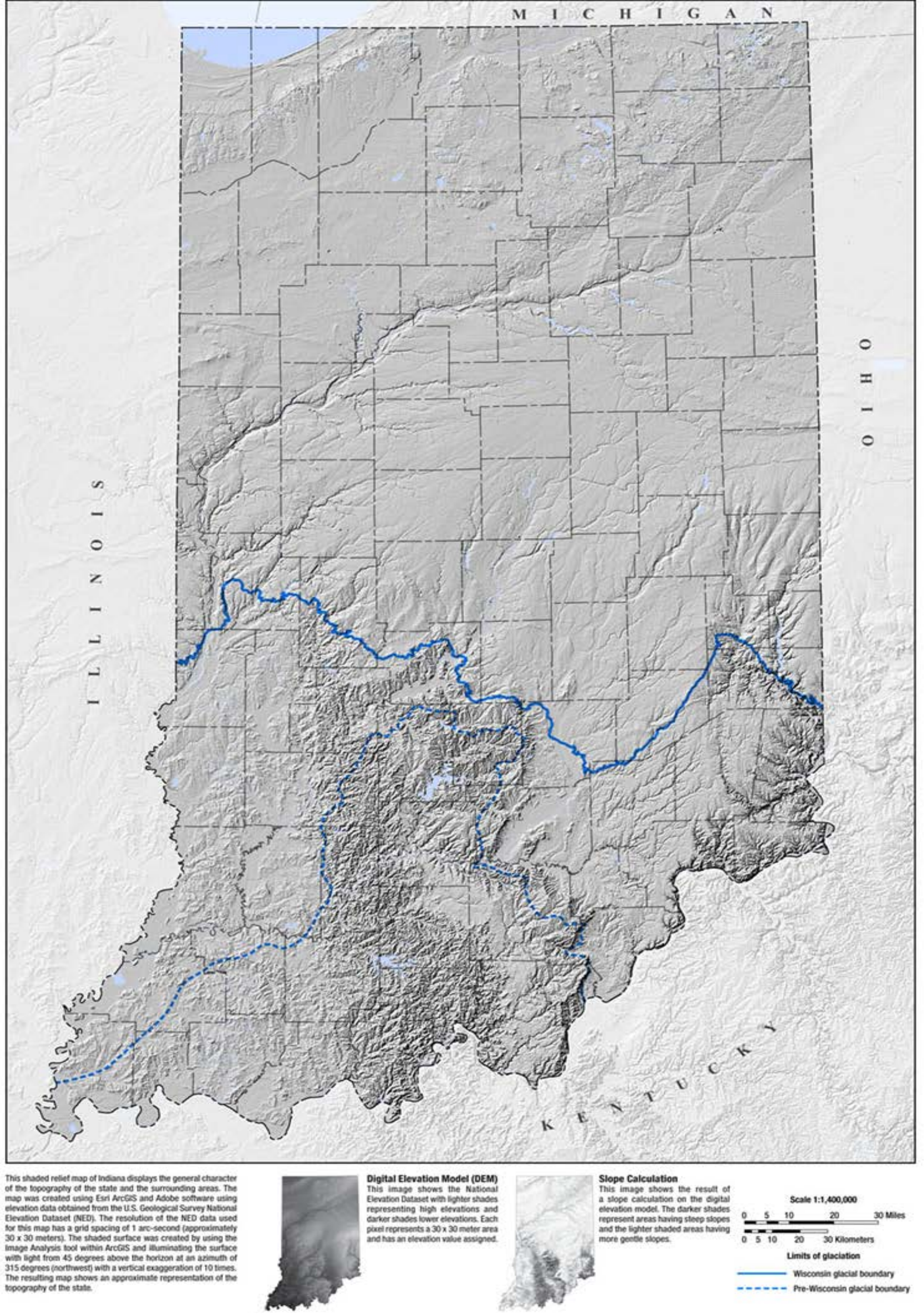
Limitations of Modeling Research

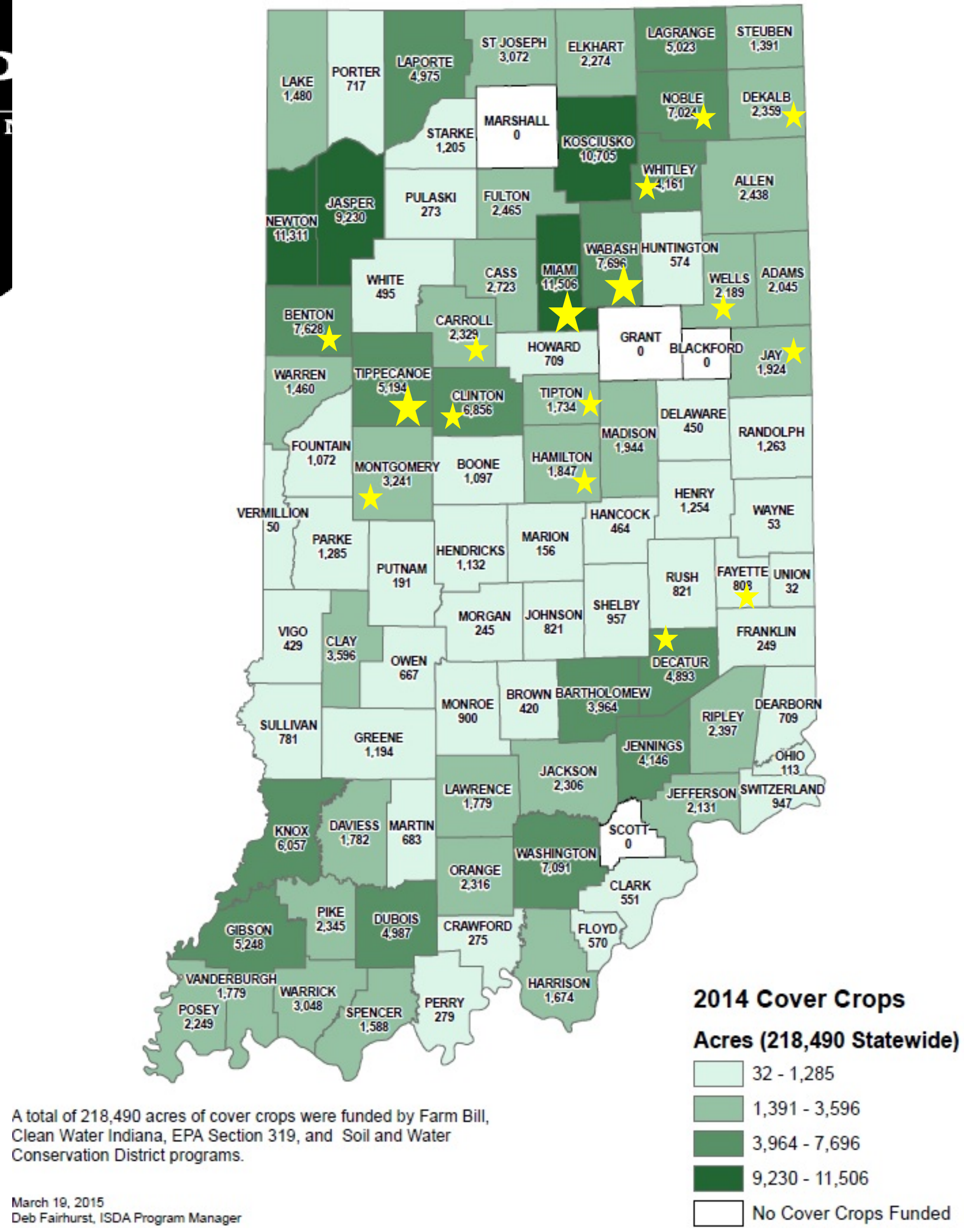
- LEAF
  - Not experimental data.
- Estimates of environmental values
  - Hard to measure.
- Only some of the benefits included in the study.
  - Other benefits excluded.

Getting Farmer Field Data

- Need much larger number of participating farmers to get reliable data sets.
- Need to limit crop rotations to the main rotations used in an area (e.g., C-C or C-S in Indiana).
- Need to focus initially in an area with relatively homogenous soil classes and slopes.
- Need to have enough farmers doing cover crops or whatever is being studied to do valid comparisons.


SOIL REGIONS OF INDIANA
SOIL REGIONS
SOIL PARENT MATERIALS; REPRESENTATIVE SOILS
1 SANDY AND LOAMY LACUSTRINE DEPOSITS AND EOLIAN SAND; Maumee, Rensselaer, Plainfield
2 SILTY AND CLAYEY LACUSTRINE DEPOSITS; McGary, Patton, Hoytville, Dubois
3 ALLUVIAL AND OUTWASH DEPOSITS; Fox, Genesee, Warsaw, Wheeling
4 EOLIAN SAND DEPOSITS; Plainfield, Oshtemo, Bloomfield
5 THICK LOESS DEPOSITS; Alford, Hosmer, Iva
6 LOAMY GLACIAL TILL; Riddles, Miami, Crosier, Brookston
7 CLAYEY GLACIAL TILL; Blount, Pewamo, Morley
8 THIN LOESS OVER LOAMY GLACIAL TILL; Brookston, Crosby, Miami, Parr
9 MODERATELY THICK LOESS OVER LOAMY GLACIAL TILL; Fincastle, Russell, Miami, Brookston
10 MODERATELY THICK LOESS OVER WEATHERED LOAMY GLACIAL TILL; Cincinnati, Avonburg, Vigo, Ava
11 DISCONTINUOUS LOESS OVER WEATHERED SANDSTONE AND SHALE; Zanesville, Berks, Wellston, Muskingum
12 DISCONTINUOUS LOESS OVER WEATHER LIMESTONE; Crider, Frederick, Corydon
13 DISCONTINUOUS LOESS OVER WEATHERED LIMESTONE AND SHALE; Eden, Switzerland, Pate
PREDOMINANTLY PRAIRIE SOILS
LAKE MICHIGAN
MICH
ILLINOIS
OHIO
KY
LEGEND
STATE BOUNDARY
COUNTY BOUNDARY
DRAINAGE
PERENNIAL LAKE
DAM WITH RESERVOIR
SCALE 1/2,000,000
SOURCE: 1970 NATIONAL ATLAS OF THE UNITED STATES OF AMERICA AND INFORMATION FROM FIELD TECHNICIANS. ALBERS EQUAL AREA PROJECTION
U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE
in Cooperation with
PURDUE UNIVERSITY AGRICULTURAL EXPERIMENT STATION
and COOPERATIVE EXTENSION SERVICE
Revised April 1986 1003822


MICHIGAN
ILLINOIS
OHIO
KENTUCKY
This shaded relief map of Indiana displays the general character of the topography of the state and the surrounding areas. The map was created using Esri ArcGIS and Adobe software using elevation data obtained from the U.S. Geological Survey National Elevation Dataset (NED). The resolution of the NED data used for this map has a grid spacing of 1 arc-second (approximately 30 x 30 meters). The shaded surface was created by using the Image Analysis tool within ArcGIS and illuminating the surface with light from 45 degrees above the horizon at an azimuth of 315 degrees (northwest) with a vertical exaggeration of 10 times. The resulting map shows an approximate representation of the topography of the state.
Digital Elevation Model (DEM)
This image shows the National Elevation Dataset with lighter shades representing high elevations and darker shades lower elevations. Each pixel represents a 30 x 30 meter area and has an elevation value assigned.
Slope Calculation
This image shows the result of a slope calculation on the digital elevation model. The darker shades represent areas having steep slopes and the lighter shaded areas having more gentle slopes.
Scale 1:1,400,000
0 5 10 20 30 Miles
0 5 10 20 30 Kilometers
Limits of glaciation
Wisconsin glacial boundary
Pre-Wisconsin glacial boundary



County	Share of cover crops land in the total farm land (%)	Dominant soil region (number)
MIAMI	6.56%	7
WABASH	3.89%	7
NOBLE	3.87%	7
CLINTON	3.07%	8
BENTON	3.00%	8
WHITLEY	2.97%	7
DECATUR	2.62%	9
TIPPECANOE	2.36%	9
DEKALB	1.47%	7
HAMILTON	1.41%	8
TIPTON	1.19%	8
CARROLL	1.14%	9
MONTGOMERY	1.13%	9
JAY	1.09%	7
WELLS	1.09%	7
FAYETTE	1.03%	9

Selection of Participants

1. Is your farm located in one of the counties listed below?

Miami	Benton	Dekalb	Montgomery
Wabash	Whitley	Hamilton	Jay
Noble	Decatur	Tipton	Wells
Clinton	Tippecanoe	Carroll	Fayette

2. In all or some of your fields, do you have a rotation only consisting of corn and/or soybeans?
3. Do you plant genetically modified corn and/or soybeans?
4. Do you have at least 5 years of historical data at the field level?

PURDUE UNIVERSITY

PURDUE AGRICULTURE

Selection of Participants

5. Do you grow cover crops between cash crop seasons ?

   if NO → Non-cover crop farmer selected

6. Have you been growing cover crops on some fields for at least 5 years?

   if YES → Cover crop farmer selected

   if NO → Use the non cover crop fields, if any

Data collection from Farmers

Data collection for CC and NCC fields

Data	Motivation
Number of acres for the field	Description purposes
Slope class of the field	Variable in the regression model
Corn or soybeans yield (bu./ac)	Dependent variable in the regression model
Tillage system	Variable in the regression model
Total amount of N (lbs./ac) only for corn years	Variable in the regression model
If field poorly drained : Drainage system of the field	Variable in the regression model

Data collection for CC fields

Data	Motivation
Cover crop and seeding rate (in lbs./ac)	Quantify the establishment cost
Seeding method	Quantify the establishment cost
Herbicide product used to terminate the cover crop and application rate	Quantify the termination cost
If participant received cost share assistance : name of the program	Quantify private benefits of cover crops or social costs of cover crops

Data collection from the Literature

Data	Motivation
Average growing season temperature (May-Sept)	Variable for the regression model
Average growing season precipitation (May-Sept)	Variable for the regression model
Corn and soybean prices	Quantify private benefits
Cash crop production costs (seed, fertilizers, herbicides, machinery repairs and others)	Quantify private costs
Cover crop seed cost	Quantify the establishment cost for cover crops
Cover crop seeding method cost	Quantify the establishment cost for cover crops
Herbicide cost for herbicides used in terminating the cover crops and cost of spraying	Quantify the termination cost for cover crops

Methodology Overview

1. Dataset conception for corn and soybeans observations
   - Field number, year dummies, **cash crop yield**, cover crop regime, soil type, soil slope, tillage regime, average temperature, and average precipitation
   - For corn dataset: nitrogen application
2. Multiple regression analysis: evaluate the difference in yields between CC and NCC fields
   - Estimated 350 fields of data need to be collected for the analysis
   - If 5 fields per farmer, 70 farmers need to be recruited
3. Benefit-Cost analysis : “with” cover crops and “without” cover crops

Summary

- The farmer's selection process will enable the researchers to have less heterogeneity in soil type, soil slope, and crop rotation.
- The data required by farmers is not complicated and represents the minimum needed to get reliable results.
- Limitation: results will only be valid for the particular area where this research is implemented, but it can be replicated elsewhere.
- The process can be repeated by selecting other areas with different soil types, soil slopes, and crop rotations.

Thanks!