# 2015 DOE Bioenergy Technologies Office (BETO) Project Peer Review

## WBS 4.2.2.10: Biomass Production and Nitrogen Recovery

Date: March 23, 2015
Technology Area Review: Sustainability

Principal Investigator: M. Cristina Negri
Organization: Argonne National Laboratory

# Goal Statement

In the context of developing tools for landscape design approach to **satisfy different societal goals** (energy security, environmental protection, low-cost commodities).

- Conduct a field study to provide performance data on one landscape design concept
- Test field methods for scale-up (remote sensing, rapid soil analysis, farmer engagement)
- Conduct watershed analysis to understand potential benefits (water quality, quantity, yields, pollinator habitat)
- Engage in stakeholder involvement to ground solutions in real world
- Develop knowledge on state of the art in demonstration methods and applications.

Project supports BETO's sustainability platform goal of by 2022 validating landscape design approaches. By 2015, validate a case study using field data.

Outcomes:

- **Field data** on sustainability metrics, yields and environmental impacts of landscape-placed bioenergy crops, **methods to test best practices** for sustainable bioenergy production
- Connecting with existing watershed conservation efforts, builds the network to secure implementation and demonstration in the longer term, provide visibility, access, **feedback from multiple stakeholders to build the basis for bioeconomy.**

# Quad Chart Overview

## Timeline

- Project start date: 04/2010
- Project end date: 09/2015*
- Percent complete: 70%

* 1-year extension under discussion

## Barriers

**<u>Feedstocks</u>**

**Ft-B**: Production – *"reliable production data…. And also needed to measure environmental effects"*

**<u>Sustainability</u>**

**St-E**: Best Practices for Sustainable Bioenergy Production

**St-G**: Land Use and Innovative Landscape Design

Other: Farmer interest and adoption potential

## Budget

| | Total Costs FY 10 –FY 12 | FY 13 Costs | FY 14 Costs | Total Planned Funding (FY 15-Project End Date |
|---|---|---|---|---|
| **DOE Funded** | $1,050K | $450K | $540K | $540K |
| **Project Cost Share** | n/a | n/a | n/a | n/a |
| **Synergistic activities*** | | | $225K | |

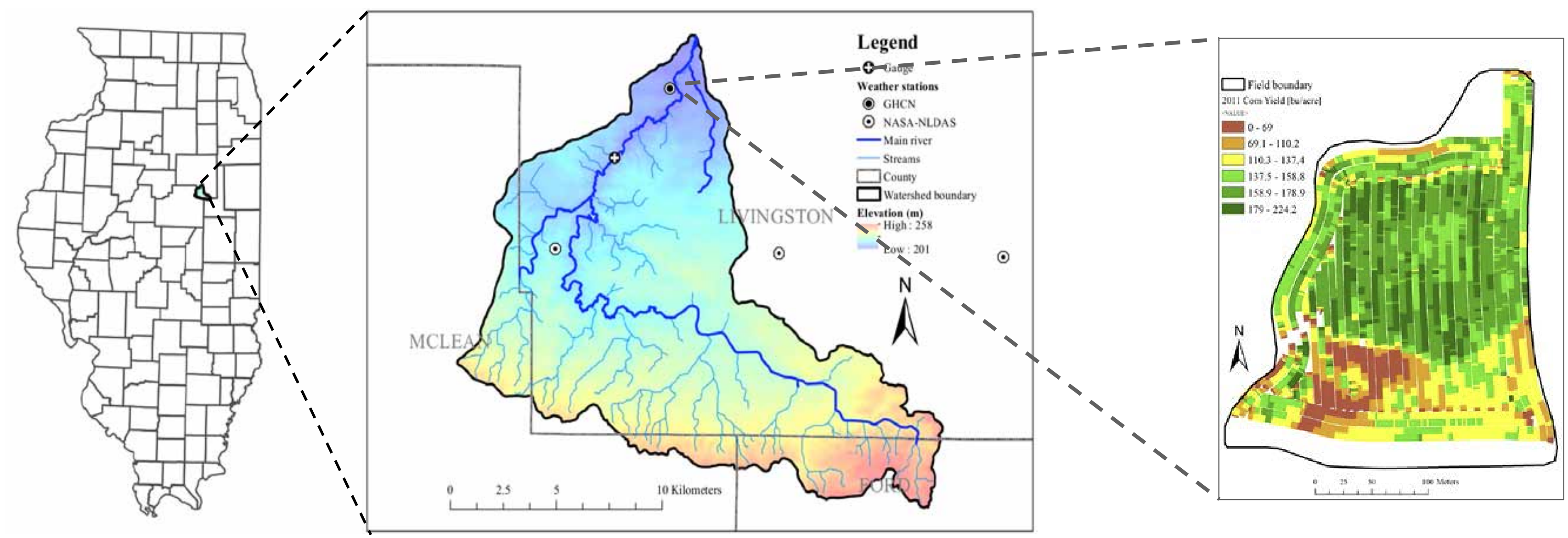
*Landscape design workshop and Blueprints development

## Partners

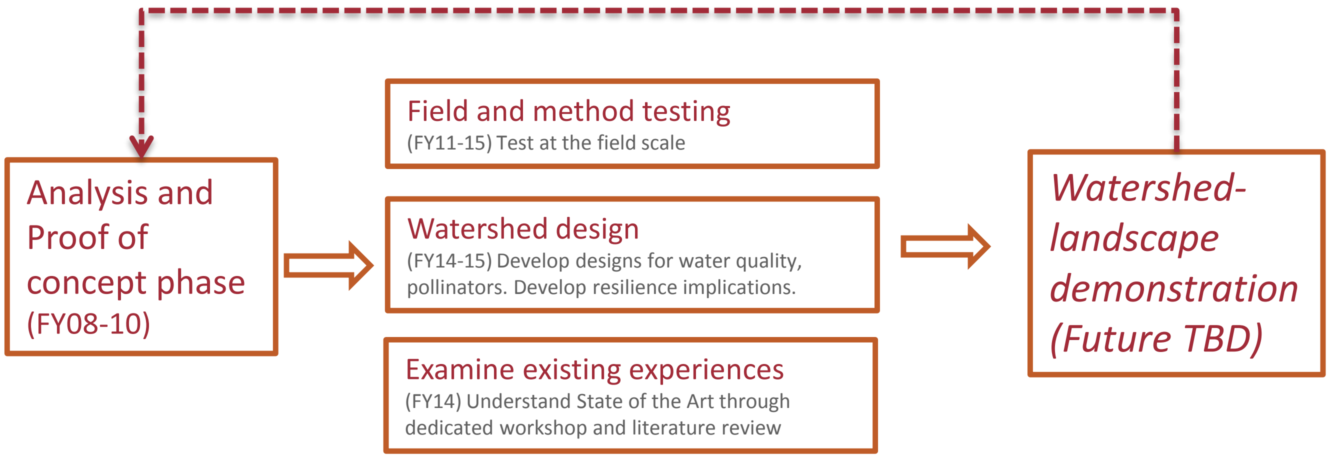
- Interactions/collaborations
  - University of Michigan
  - State University of New York/ ESF
  - Idaho National Laboratory
- Non-technical project management partners
  - Livingston County SWCD and NRCS
  - Conservation Technology Information Center
  - ILEPA

# 1 - Project Overview

- Develops Landscape Design, an alternative way to address the land use change and environmental impact concerns of bioenergy production. Designing “How to deploy bioenergy” from the ground scaling up
- Leverages strengths of bioenergy crops to address the ills of current agricultural system through holistic resource management
- Proof of concept in 2010 led to a field study (ongoing) on nitrogen recovery by bioenergy crop buffer
- Field study led to a case study in the Indian Creek watershed (ongoing) inclusive of modeling and outreach to community of farmers and other stakeholders
- Develops methods for scale up of monitoring and stakeholder acceptance in light of a potential future demonstration.



# 2 - Technical Approach




## Metrics:

- Target: Achieve 30-90% N-$NO_3$ reductions at field edge based on current knowledge (Smith et al., 2013)
- Go/No-go Decision Points:
  - FY10 – propose field study if model and proof of concept provide favorable results
  - FY13 - based on precipitation, select crop to replant
  - FY15 - based on growth, propose an additional year of project

Smith, C.M., David, M.B., Mitchell, C.A., Masters, M.D., Anderson-Teixeira, K.J., Bernacchi, C.J. & DeLucia, E.H. (2013) Reduced Nitrogen Losses after Conversion of Row Crop Agriculture to Perennial Biofuel Crops. *Journal of Environmental Quality*, **42**, 219-228.

# 2 – Management Approach

**Critical success factors**:

- Identify value to farmers
- Cost-effectiveness of data collection
- Identification of a viable end use market.

**Progress measurement**:

- Quality and extensiveness of field data collection
- Milestone tracking
- Go/No-go decision points to redirect and assess project direction.

## Challenges:

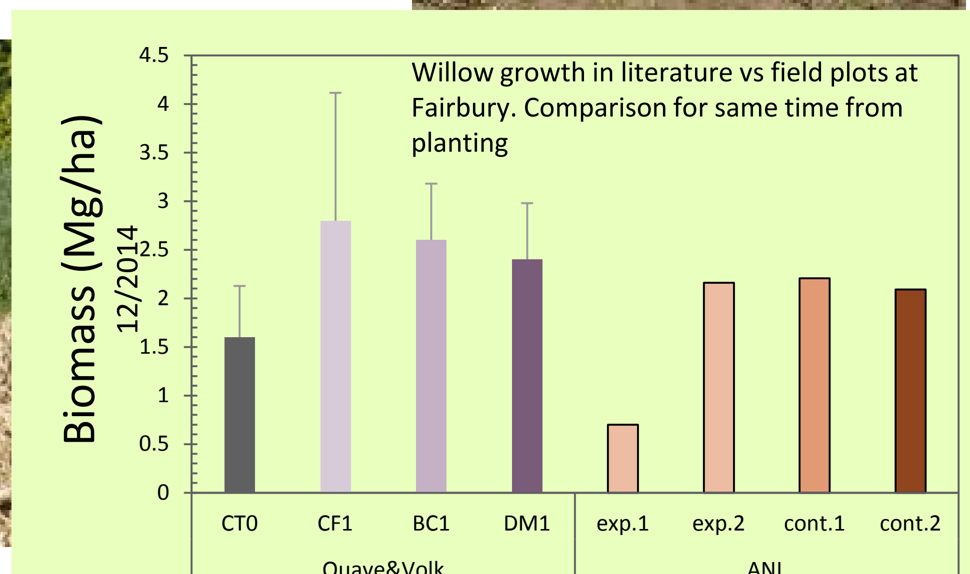
- Farmer acceptance and feedback will be critical to adoption of the approach: project builds the R&D and farmer connections in parallel by creating opportunities for feedback through meetings, workshops and farmer engagement study, discussion of local markets for produced biomass.
- Maintaining research-grade conditions at the field scale and attaining robust statistical design was the immediate challenge which required blending of different approaches. Challenge was addressed previously and continuously re-evaluated with addition of monitoring points/methods.
- Scaling up to watershed research will require significant effort to ensure participation and the cost-effective collection of sufficiently detailed data for planning. Project is testing precision agriculture approaches to develop rapid planning methodologies.

| Milestones | FY08-FY10 | FY11-FY13 | FY14 | FY15 | *FY16* |
|---|---|---|---|---|---|
| Complete resource assessment and proof of concept | ……………………X | | | | |
| Identify field site, NEPA, install monitoring system & baseline | | ………………X | | | |
| Plant bioenergy crop (willow) | | …………X… *X | | | |
| Monitor sustainability indicators | | …………………X | …………………X | ……… * …..X | *……………X* |
| Design alternative watershed land use | | | …………………X | ………………X | |
| Develop model for farmer involvement & conduct workshop | | | …………………X | | |
| Organize Landscape Design workshop series and report | | | …………………X | | |
| Watershed scale demonstration plan drafted | | | ………………X | | |
| Blueprints summary completed | | | | …………X | |

* Go/No-go decision point

# 3 – Technical Accomplishments/ Progress/Results

## Field trial: Progress from willow re-planting – May 14, 2013 through growth to Winter 2015

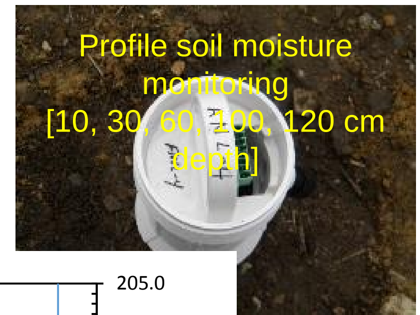


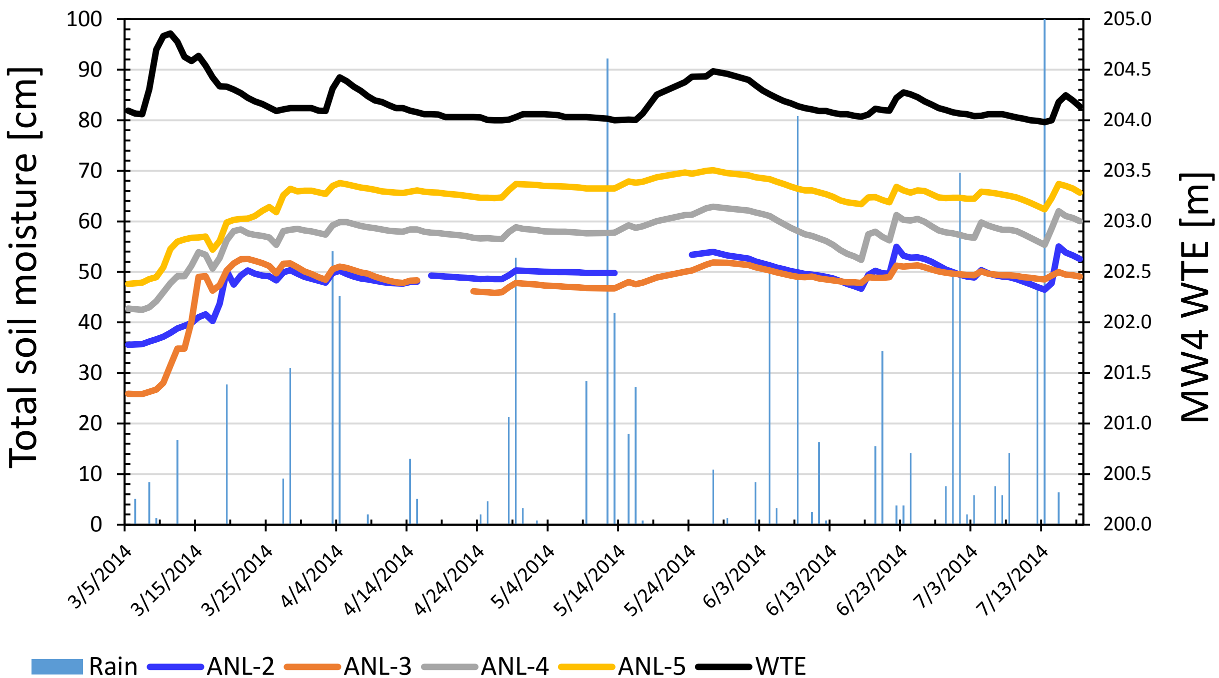

Note: no fertilizer in Willow plots, control refers to productive soil conditions

# Field monitoring infrastructure





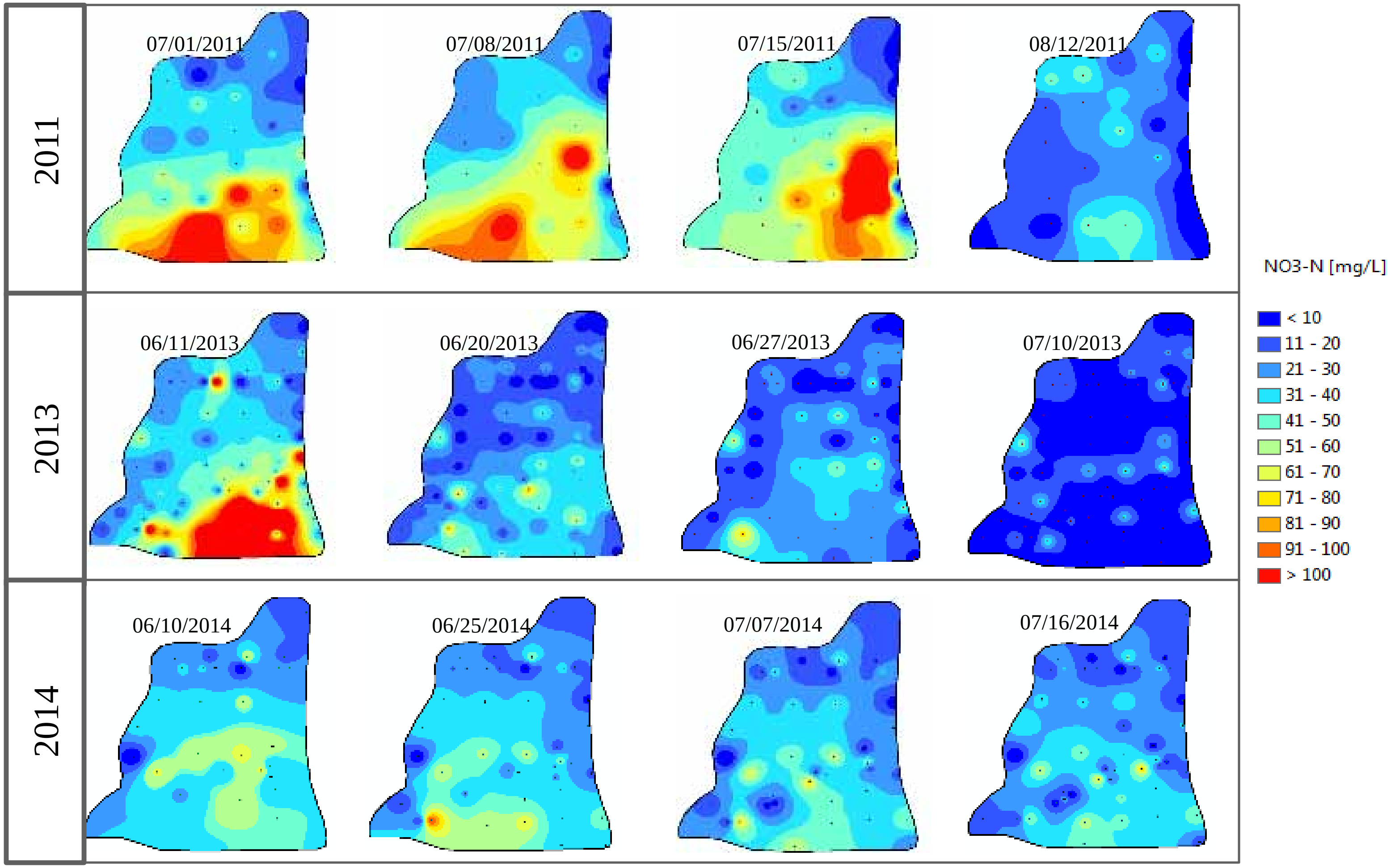



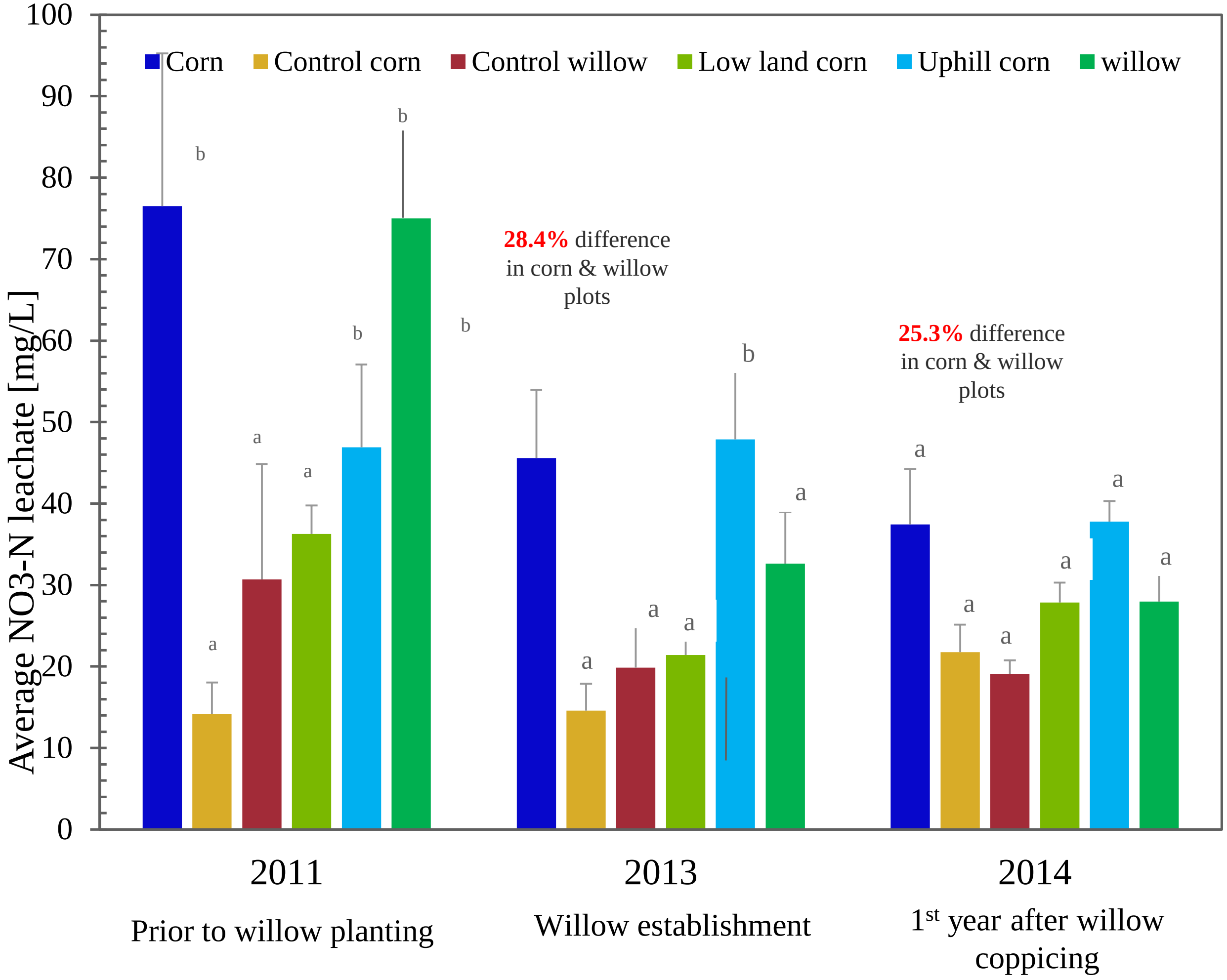

**Total soil moisture in top 150cm soil layer**

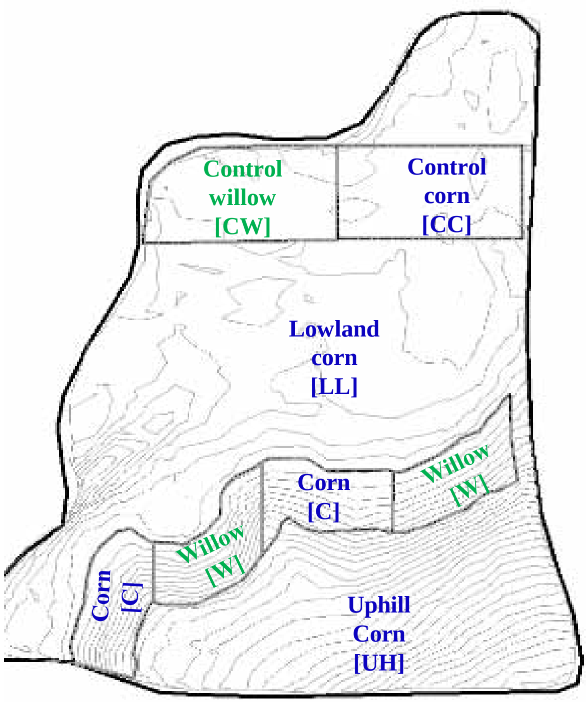
| | |
|---|---|
| ANL-2 | Corn 2 |
| ANL-3 | Corn 1 |
| ANL-4 | Willow 1 |
| ANL-5 | Willow 2 |

# Spatial-Temporal variation of $NO_3$-N Concentrations (mg $L^{-1}$) at 1.2 - 1.5m depth



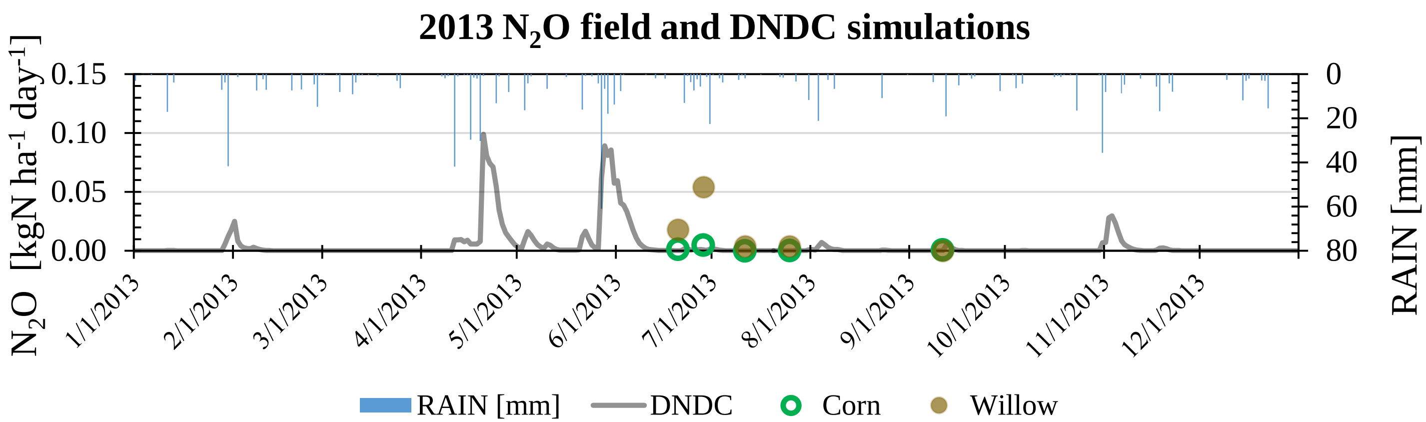
# $NO_3$-N leachate analysis

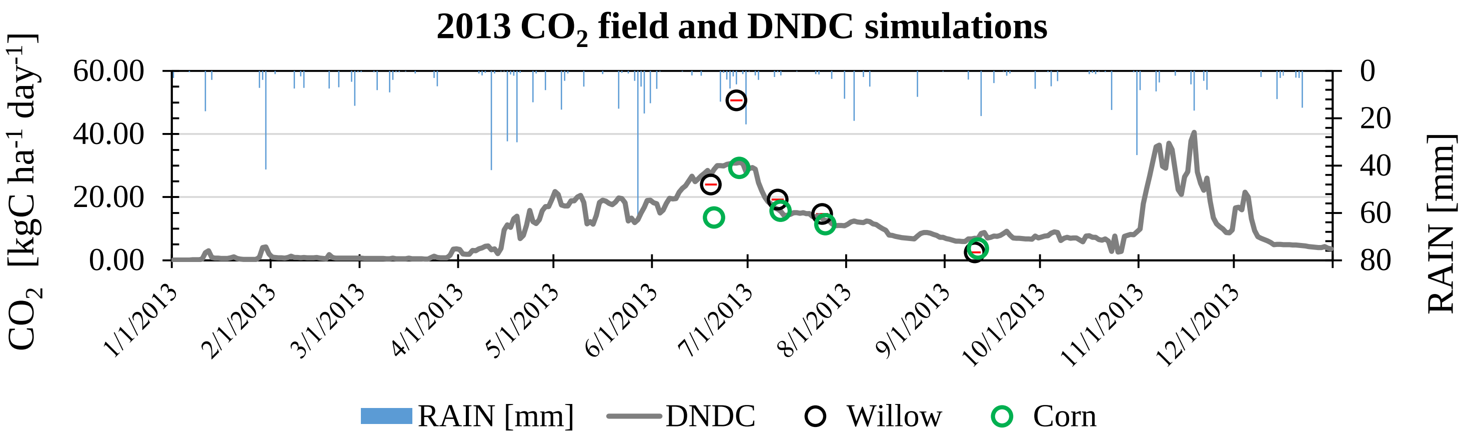


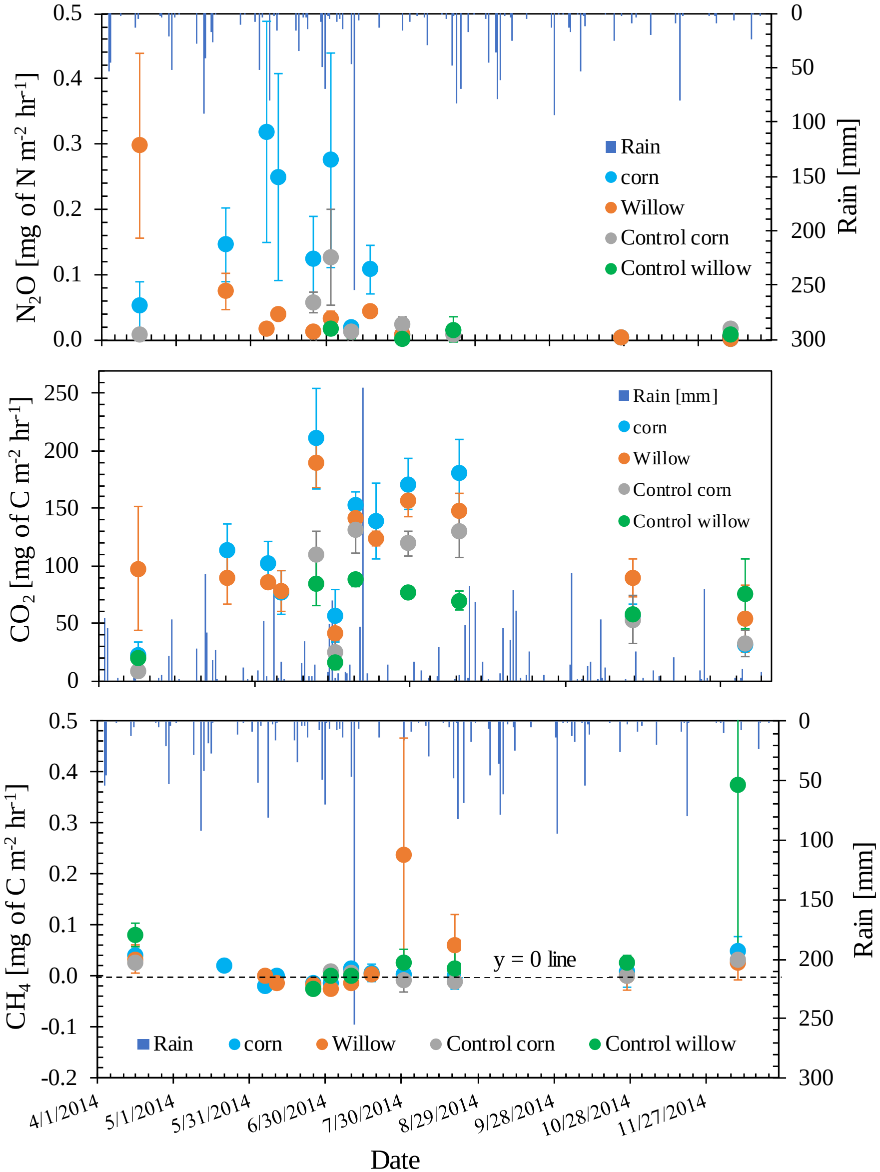
# Greenhouse Gas Flux monitoring

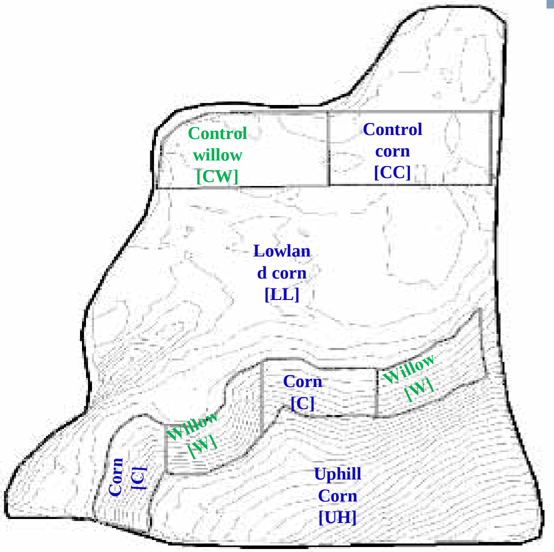
- Collected greenhouse gas flux samples and developed streamlined procedure
- Added deeper soil gas sampling probes to monitor N2O evolution at 4 feet bgs – next to static gas flux chambers to determine extent of denitrification at depth
- Analyzed some 700 samples in 2014: $CO_2$, $N_2O$, $CH_4$.
- Modeled field biogeochemistry using DNDC

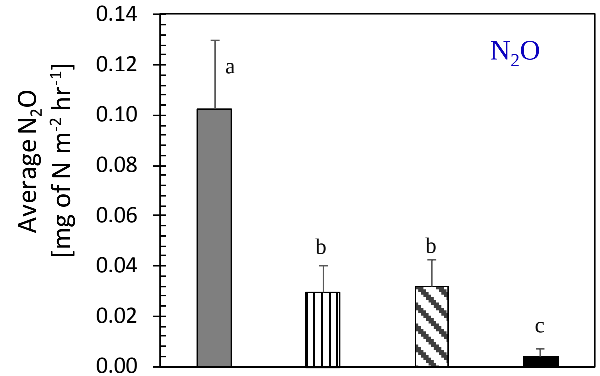


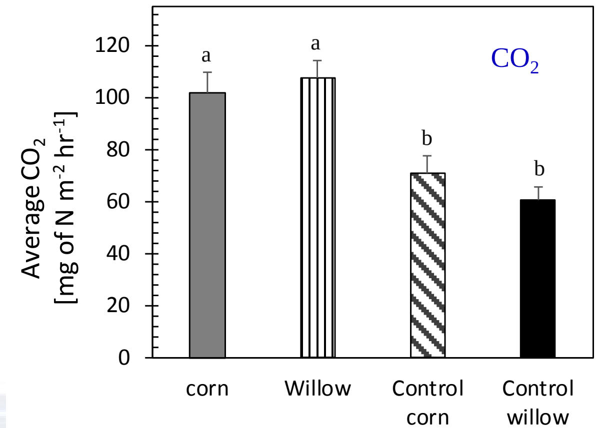



# 2014 GHG emissions

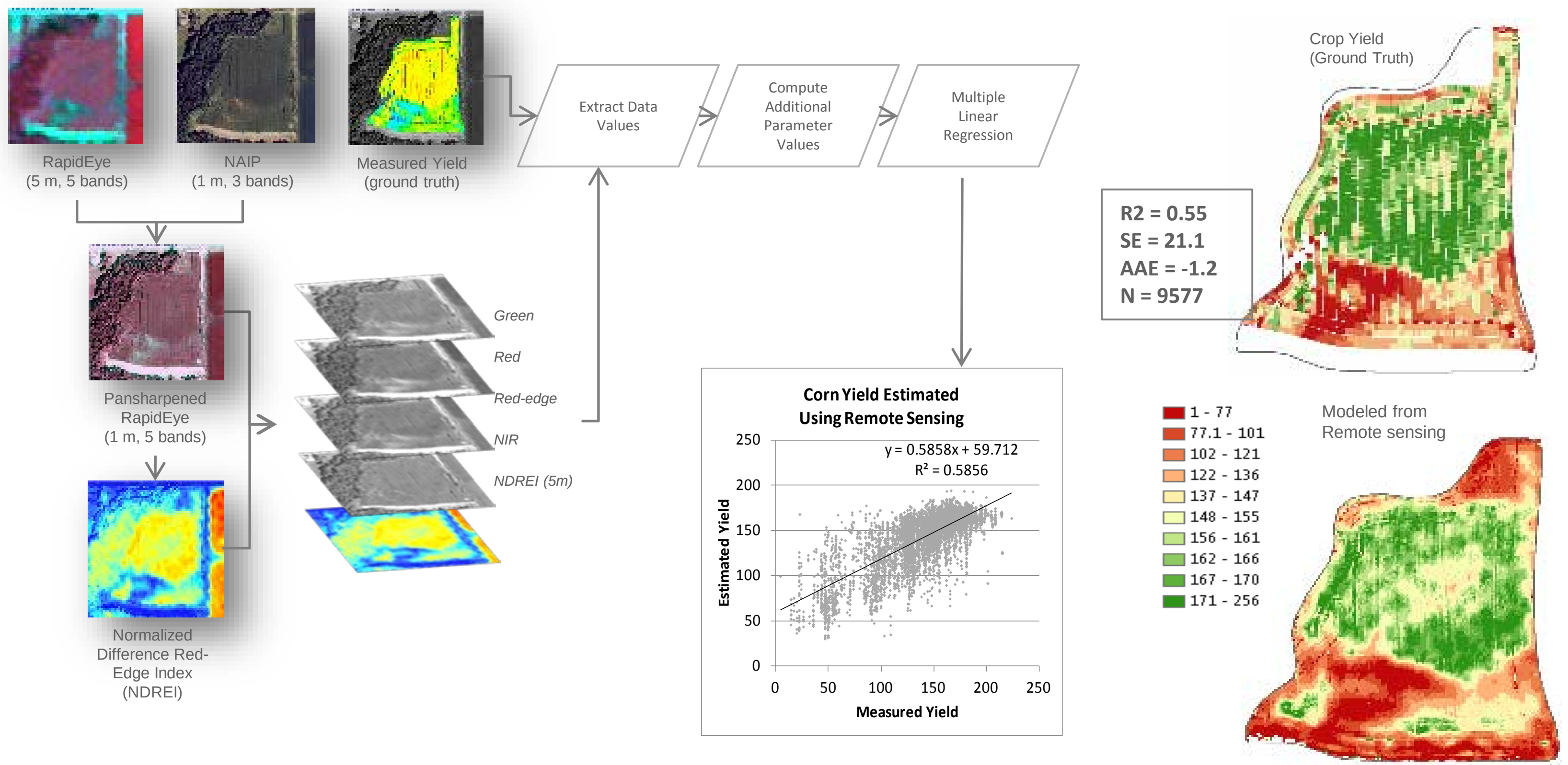


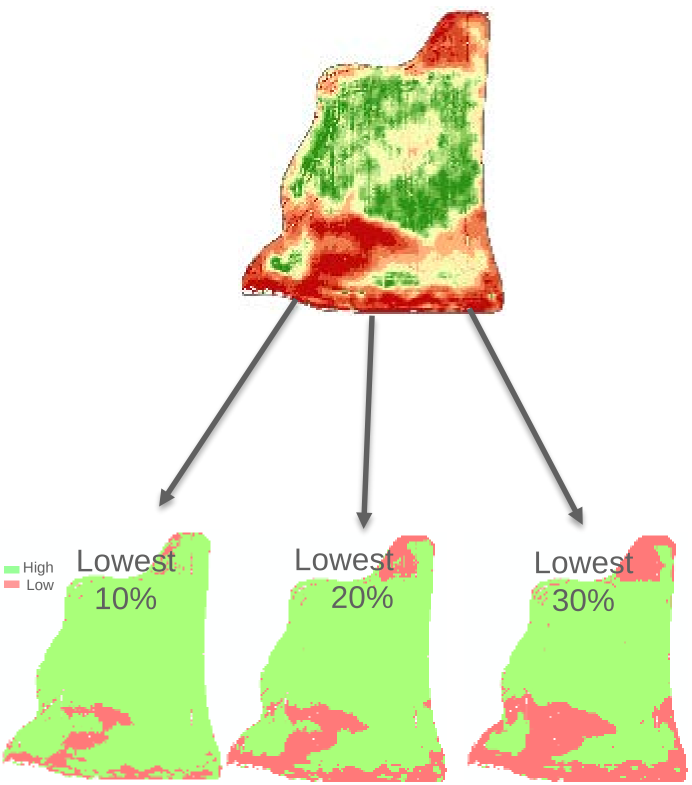



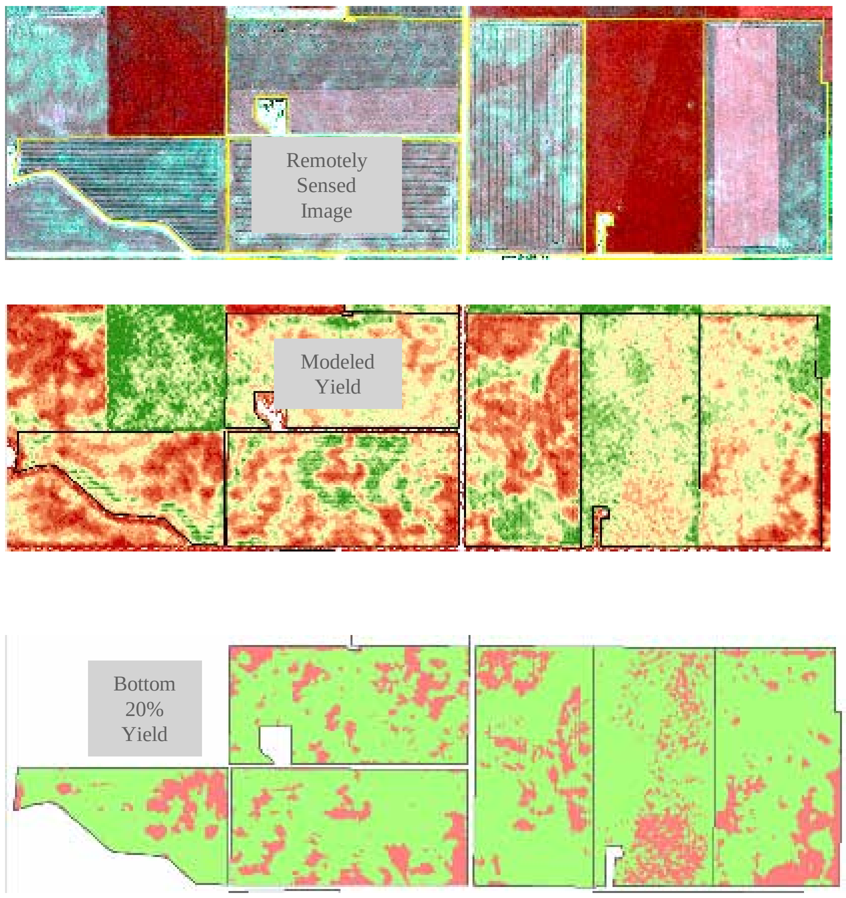



# Testing methods for scale-up:
# a- Estimating yield using remotely sensed imagery

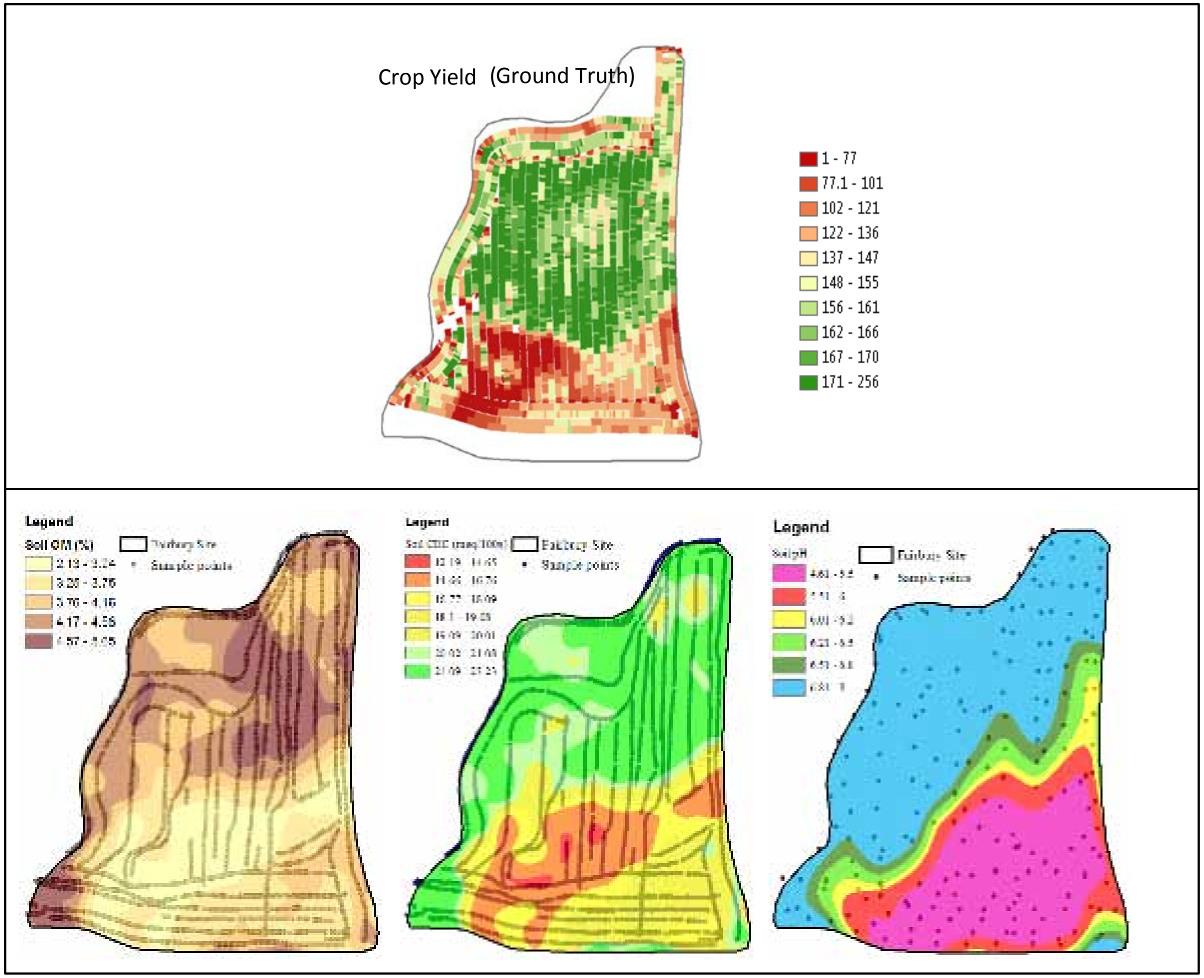


# Testing methods for scale-up:
# b-Delineating underproductive land - from field to watershed



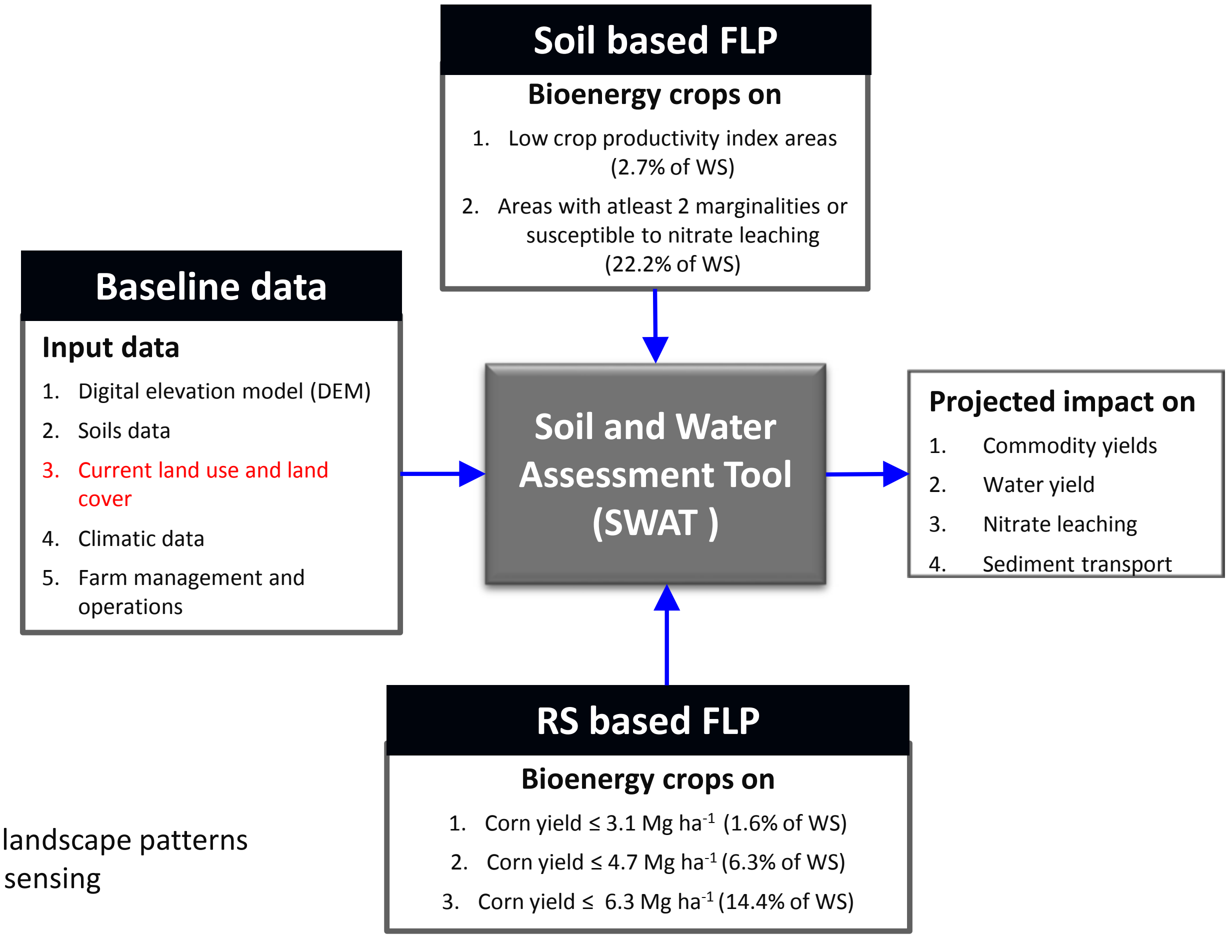



# Testing methods for scale-up:
# c- Rapid soil mapping at the Fairbury site



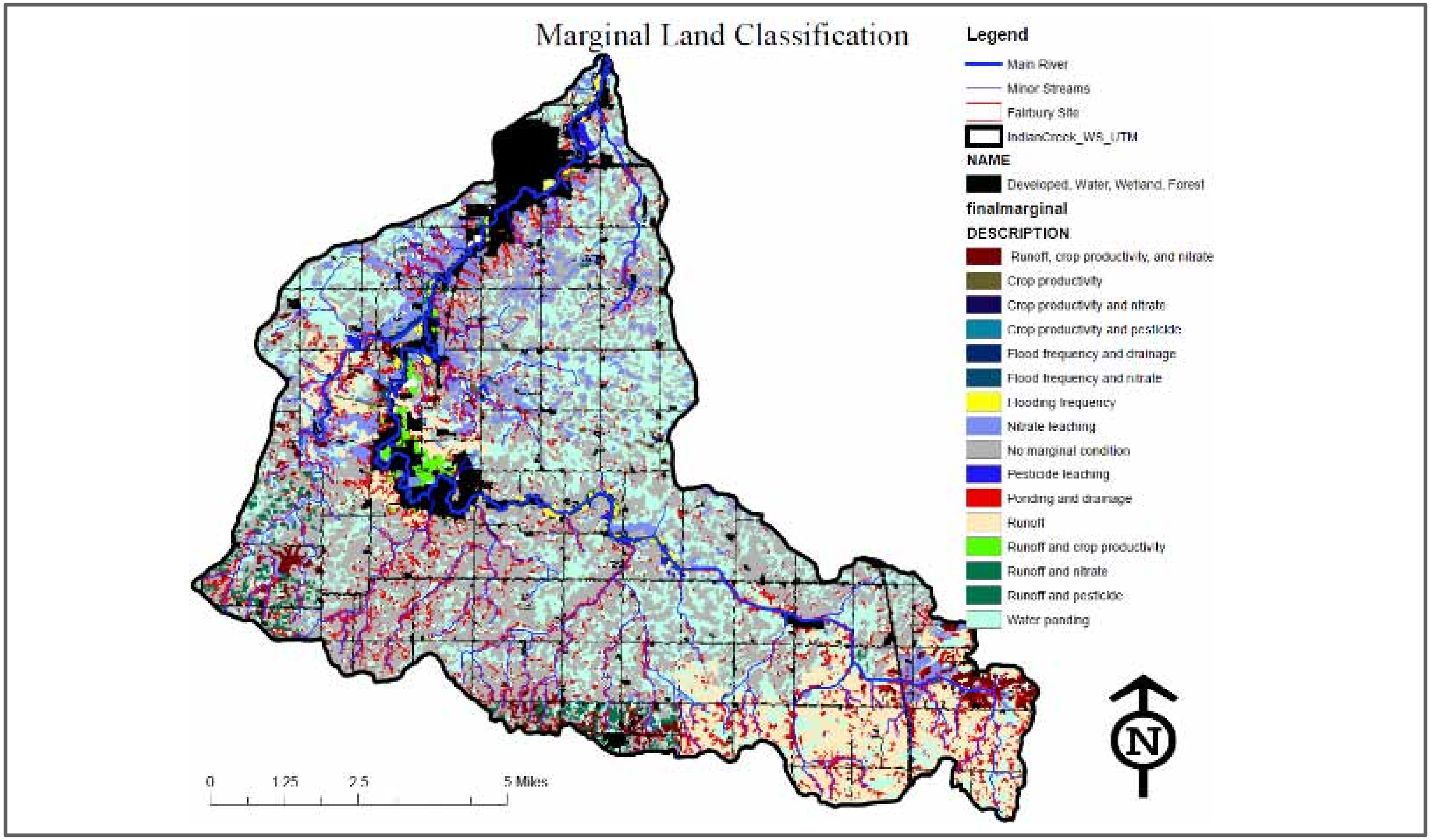

VERIS® soil mapping and image provided by Farm Map Solutions, LLC.

# Watershed scale design and assessment



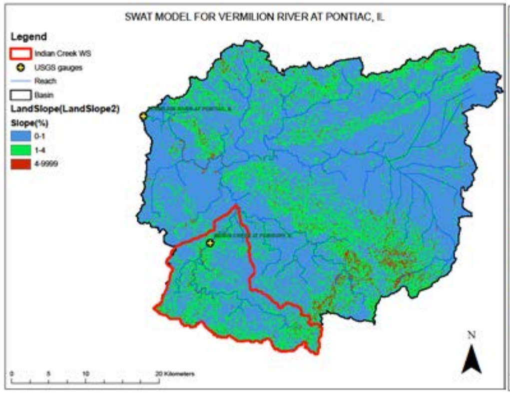

FLP = future landscape patterns
RS = remote sensing

# Watershed analysis of underproductive and vulnerable land (marginal)

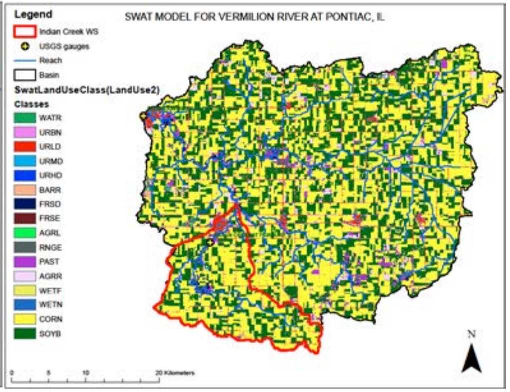


# Testing methods for scale-up: Donor watershed method
## - when long term watershed data are not available

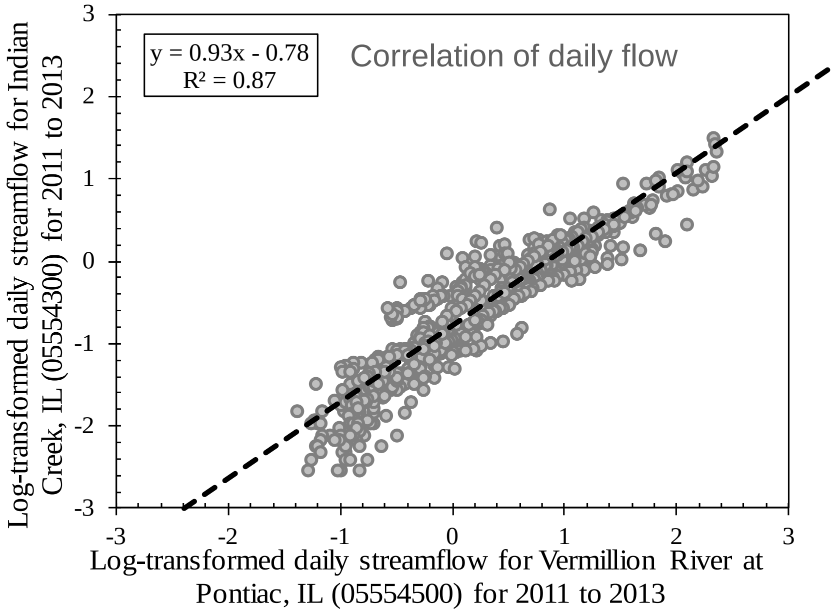
- Similarity between slope and LULC in the Vermilion River at Pontiac, IL vs Indian Creek Watersheds
  - Land cover distribution: 31% corn-soybean, 29% soybean-corn, and 8% continuous corn rotations
  - Topography: about 67% has a 0 – 1% slope
  - Tile drainage coverage: 87%
- The high correlation ($R^2$ = 0.87) gage for extending Indian Creek daily streamflow of the Line of organic correlation confirms Vermilion River as an appropriate index or donor




Slope distribution




Land cover distribution

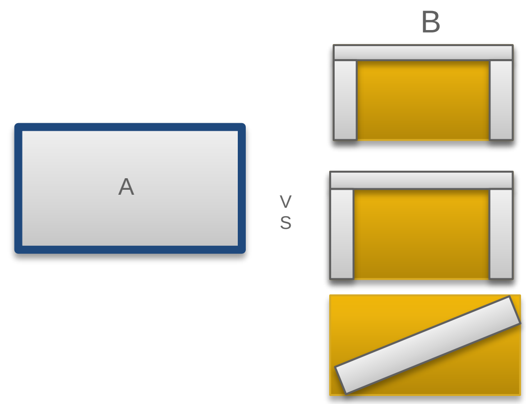


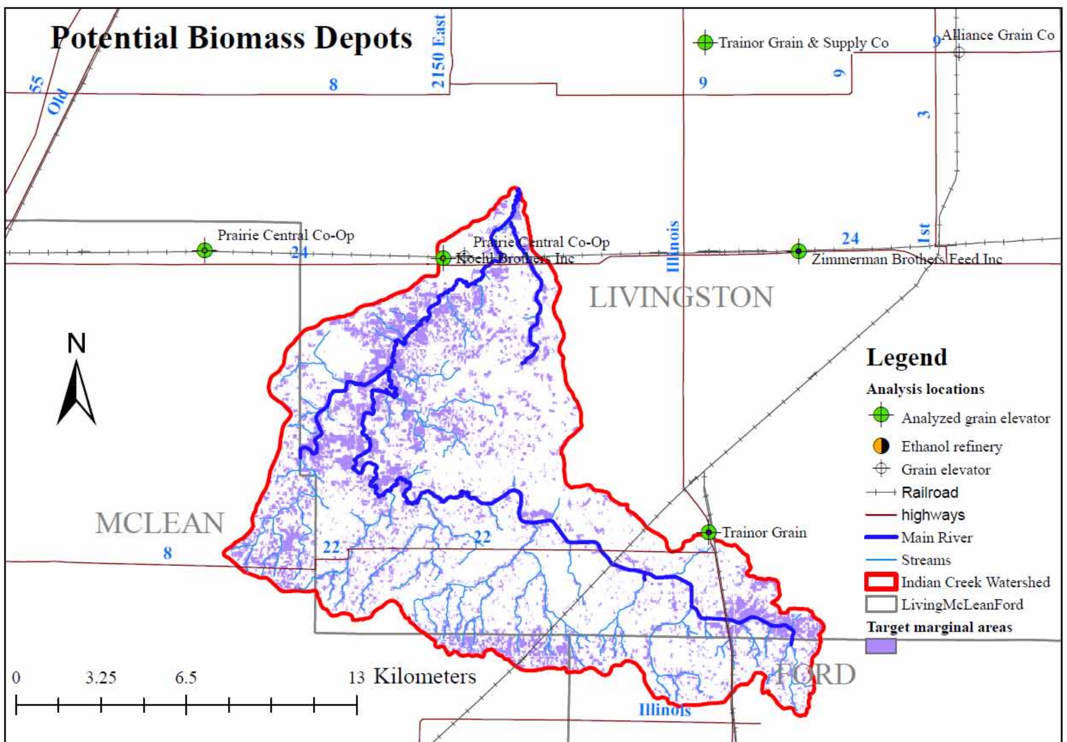
# Biomass logistic system analysis -precursor to economic analysis
## in collaboration with INL

### Economics

- Production
  - Cost estimates developed by others are acceptable at this field site but not generalizable (slope, remote location, irregular field)
  - Consider impact on corn production costs (time)
- Logistics
  - Depend on spatial configuration, transport from field.
- Farmer profit:
  - from crop
  - from ecosystem services

Need: to determine how biomass harvesting and transport from A is different than the same from B

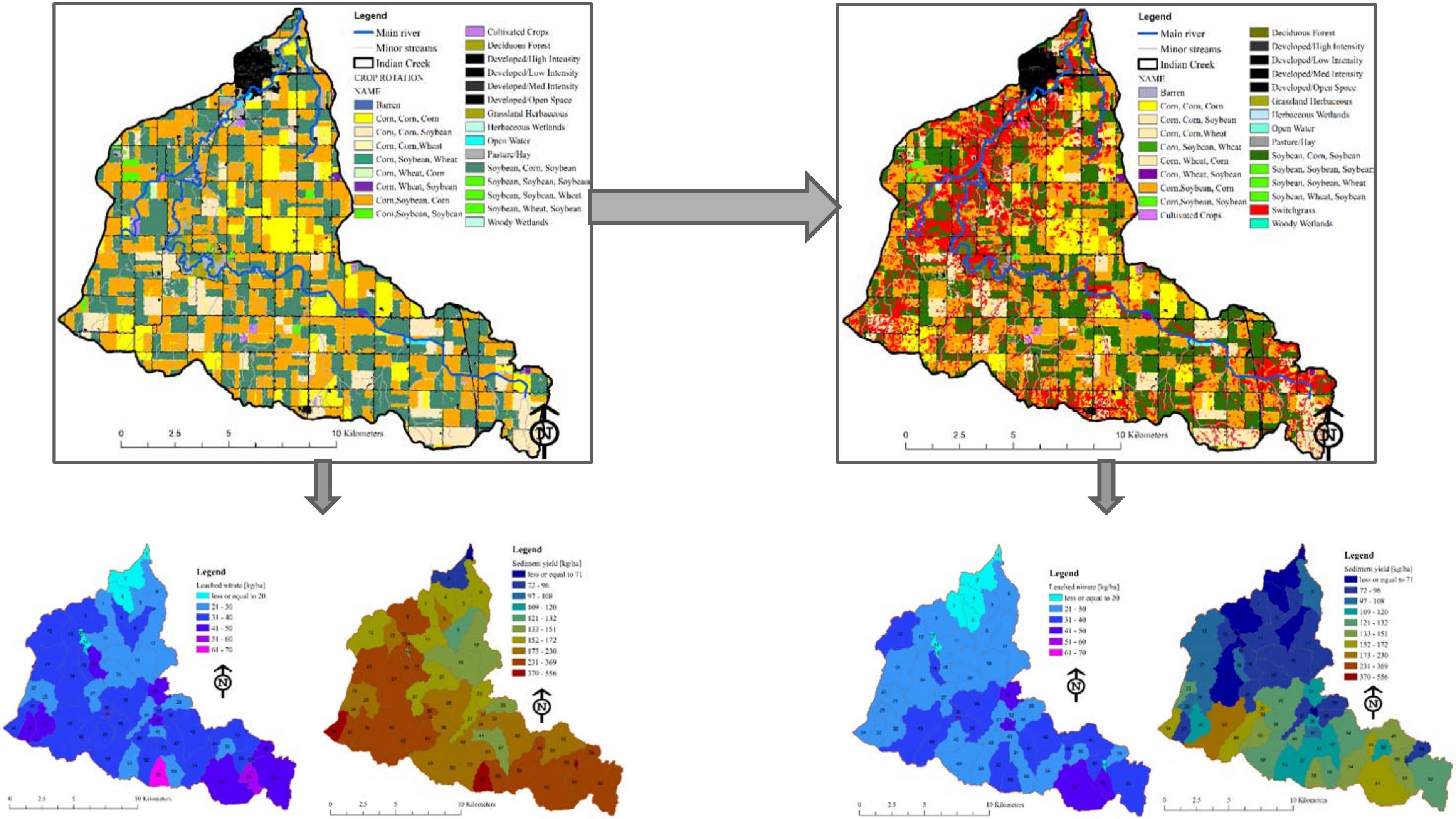



### What we learned from a preliminary run

- Used our land marginality data and FLP as basis
- Hypothesized current grain elevators as locations for depots
- Hypothesis was that distributed collection would have impact on cost ratios
- Useful to determine what to focus on:
  - Need to focus on transport from field
  - Need sensitivity analysis.
- Work ongoing 2015 Q2.

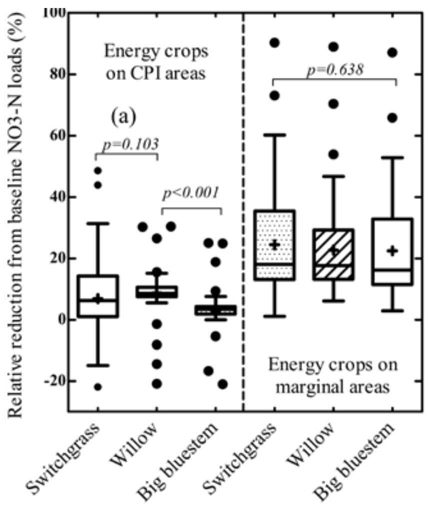
# Designs- future landscape pattern and simulation results
## leached nitrate and sediment



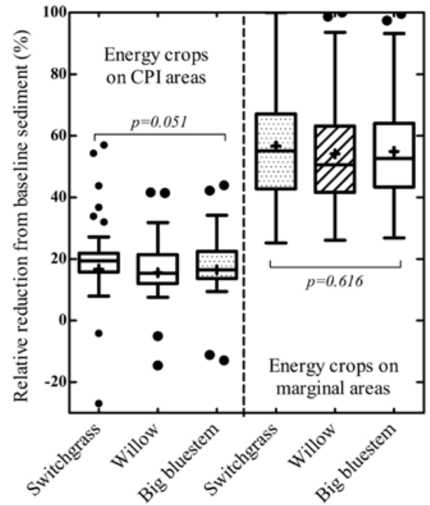
# Results from watershed design assessment

**Soil data based analysis**

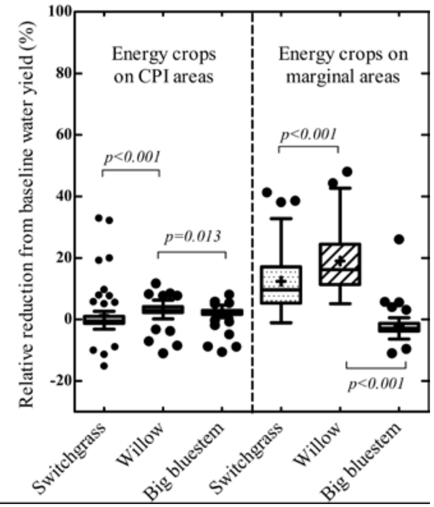
**NO$_3$-N reduction (%)**




**Sediment reduction (%)**

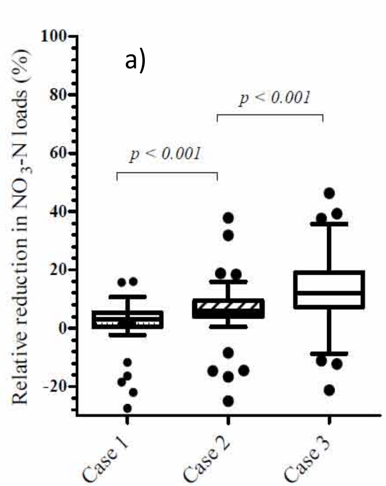



**Water yield reduction (%)**

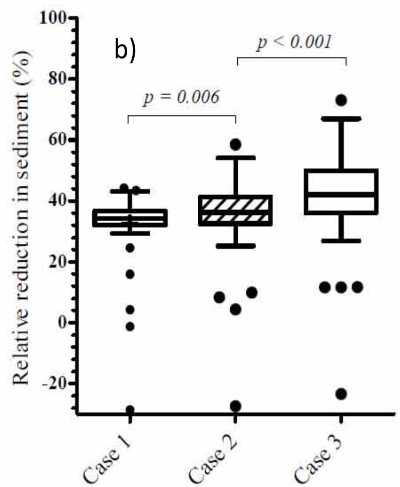



**Remote sensing based analysis**

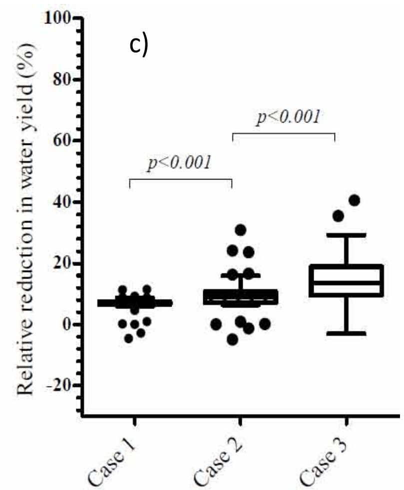
**NO$_3$-N reduction (%)**




**Sediment reduction (%)**




**Water yield reduction (%)**

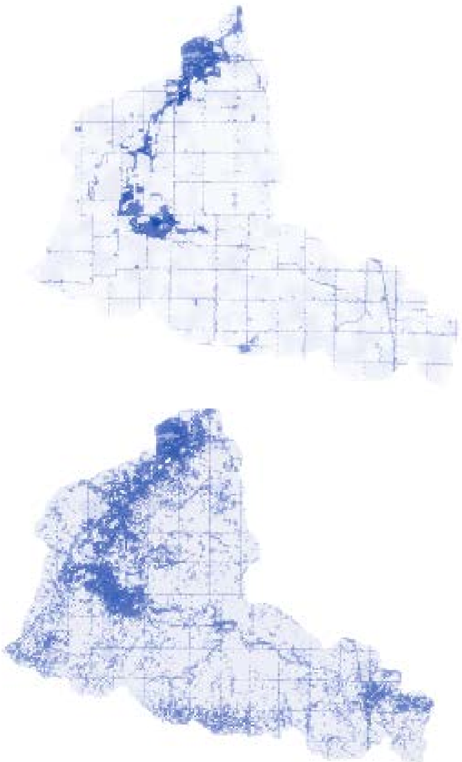



**Low corn yield thresholds**

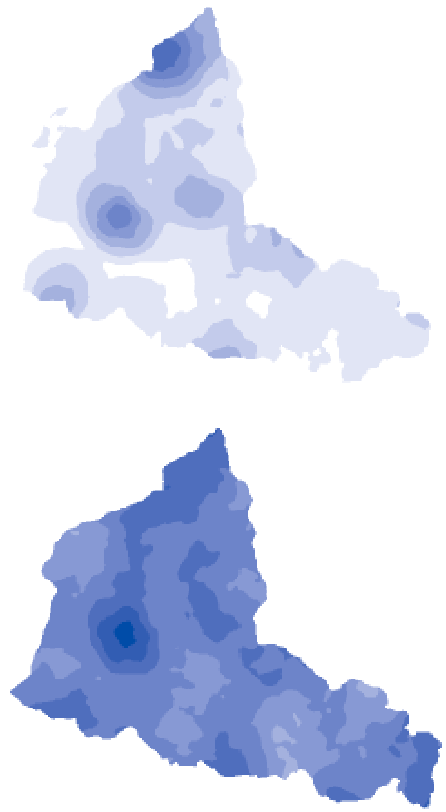
1. Case 1: 3.1 Mg ha$^{-1}$ (50 bu/ac)
2. Case 2: 4.7 Mg ha$^{-1}$ (75 bu/ac)
3. Case 3: 6.3 Mg ha$^{-1}$ (100 bu/ac)

## Modeling pollinator habitat – Indian Creek, current crops vs switchgrass for water quality design. John Graham, U. of Michigan

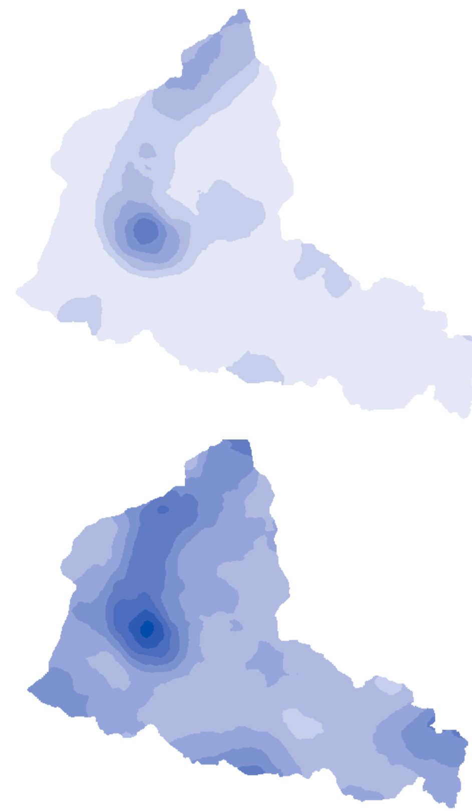
Pollinator nesting index,
InVEST model



Pollinator diversity,
Bennet Index



Pollinator abundance,
Bennet Index



# Stakeholder engagement in the watershed and regionally

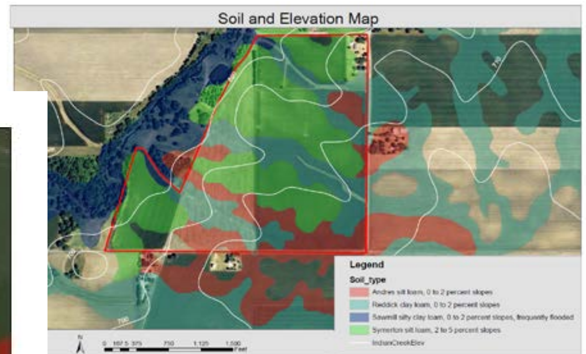
- March 8, 2013 - workshop in Fairbury on bioenergy crops, 45 people attending, experts presented agronomics and uses of major bioenergy crops
- Presented at the CTIC National conservation tour in July 2013
- Held several planning meetings with local County NRCS/Soil Water Conservation District technical staff and consultants - spring 2014
- Conducted Farmer workshop in August 2014
- Presented at Chicago Farmer Forum, February 2015. Broader audience interested in long-term vision.
- Other regionally relevant venues are important to build interest.

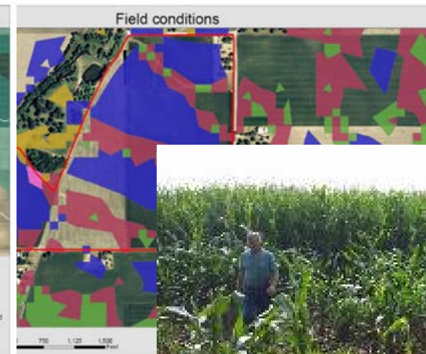
**Key points**

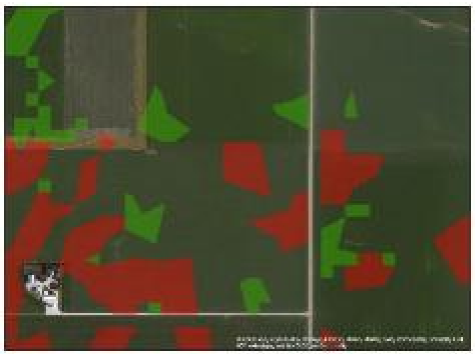
- Initial polling showed that using sub-productive or “nuisance“ land for bioenergy perennials is attractive to farmers
- Suggestions or ideas included opportunities to streamline farm operations
- Flexible-use crops that can double as forage may be attractive while markets build
- Interest in farm energy self-sufficiency
- Interest in climate-related change management needs, adaptation
- Periodic workshops may be beneficial and cost effective

# Seeking Farmer and stakeholder input - method testing -
(collaboration with U. of Michigan)

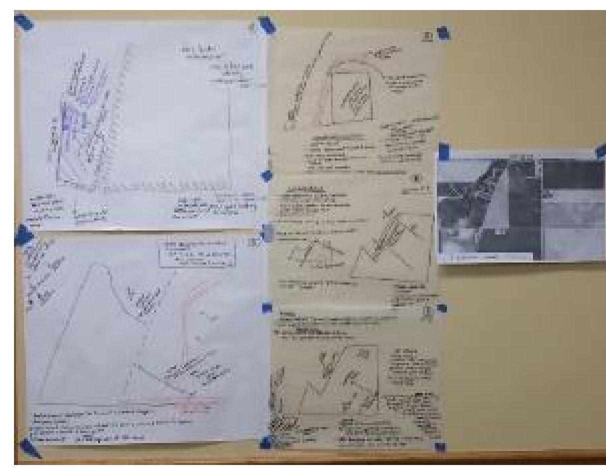
- Farmer workshop  August 4-5, 2014 sought input from farmers based on 4 scenarios for 2030
- Visualizations of landscapes as boundary object to gather discussion and consensus
- Developed framework for Agent Based Modeling of farmer decisions











# 4 - Relevance

**Barriers addressed**

***Ft-B:*** : answers sustainability and productivity questions related to bioenergy feedstock production

***St-E***: developing and testing Best practices for Sustainable bioenergy production

***St-G:*** Develops science-based, multi-stakeholder strategies for Innovative bioenergy Landscape Design.

**Project is relevant to**:

- DOE and BETO: through WBS element "Sustainable System Design" provides field data and designs for sustainable bioenergy landscapes. Addresses a critical "how" question at the base of sustainability analysis and land use change.
- Contributes to fulfilling BETO goal of, by 2022, validating landscape design approaches.
- Conversion industry: tests ways to intensify biomass supply and prepares community for investments in bioenergy.
- Rural communities: Considers needs and barriers within farming community and gives them an opportunity to be part of the design process and options to diversify their production.
- Through developing partnerships, the project provides a substantial opportunity to link suppliers and end users of biomass for integrated deployment at the landscape scale.
- Society: provides concepts and data to develop alternative land management systems to deliver food, feed, energy and ecosystem services.

# 5 - Future Work

- Continue field monitoring and harvest willows either in December of 2015 or 2016
- Analysis of landscape-based biomass logistics in the watershed (with INL)
- Develop economic framework and analysis
- Quantify watershed scale GHG emissions and SOC under different Future Land Patterns (FLP)
- Build the framework for assessing the resilience of designs to climate disruption and assess which designs could provide the most benefits in a locally scaled climate change scenario.

# Summary

## Overview and approach

Project develops Landscape Design tools to address LUC and environmental concerns. Leverages strengths of bioenergy crops, and conducts field testing to watershed scale-up provides data to:

- Understand productivity, environmental performance and economics of landscape-placed bioenergy cropping recovering nutrients lost from farming
- Test methodologies for land targeting, crop deployment and monitoring
- Develop approach for stakeholder involvement and provide visibility
- Develop watershed designs for water quality and pollinator habitat
- Develop a plan for an on-the-ground watershed demonstration.

## Relevance

- Relevant to BETO's WBS element "Sustainable system design"
- Supports convertsion industry by advancing integrated approaches to strengthen rural bioeconomies and environment
- Provides field data and tools for designing best practices and validating case studies
- Proposes designs for bioenergy systems with minimized LUC and environmental impacts
- Addresses Barriers in sustainability and sustainable feedstock supply including farmers concerns.

## Accomplishments

- Successfully established field site, collecting yield and environmental data that are beginning to show buffer impacts
- Tested promising approach from precision ag and remote sensing to baseline and monitor at larger scale
- Hosted several farmer meetings, used on site visit, visualizations and geospatial information to elicit comments and ideas for farmer-vetted designs
- Established a solid connection with farming community and early adopters
- Identified vulnerable or underproductive land in the watershed for bioenergy, modeled potential environmental services and productivity
- Developed a broad partnership to carry out demonstration in the watershed.

## Future Work

- Continue field monitoring and harvest willows
- Complete analysis of landscape-based biomass logistics in the watershed (with INL)
- Develop economic framework and analysis
- Quantify watershed scale GHG emissions and SOC under different Future Land Patterns
- Build the framework for assessing the resilience of designs to climate disruption.

# Additional Slides

# Responses to Previous Reviewers' Comments

- Logistics and economics were not considered
  - Response:
    - Lack of data prevented us from carrying out this analysis in the past.
    - We have now completed a watershed scale analysis and a design to work from
    - Began work with INL on logistics, 2015 Quarter 2
    - Asked farmers relevant questions on feasible approaches
    - Ecosystem services role needs also to be included in the economic analysis

- Uncertainty on how the findings/approach can be scaled up
  - Response: We have used our field site and watershed case to test methods for efficient scale-up in modeling, data acquisition, area selection.

# Select Publications, Patents, Presentations, Awards, and Commercialization

1. John B. Graham, J. I. Nassauer, M. C. Negri and H. Ssegane. 2015 **Engaging Stakeholders: Designing and Using Landscape Scenarios as Boundary Objects in Participatory Research for Bioenergy Development.** Submitted to *Ecological Applications*.
2. Ssegane, H., and M. C. Negri. **Designing a Sustainable Integrated Landscape for Commodity and Bioenergy Crops in a Tile-drained Agricultural Watershed. 2015** (*Submitted to GCB Bioenergy* –revisions)
3. Ssegane, H., M. C. Negri, J. Quinn and M. Urgun-Demirtas. **Multifunctional Landscapes: Site Characterization and Field-Scale Design to Incorporate Biomass Production into an Agricultural System.** (*Submitted to Biomass and Bioenergy –revisions*)
4. Hamada, Y., H. Ssegane, and M. C. Negri. **Mapping Intra-Field Yield Variation Using High Resolution Satellite Imagery to Integrate Bioenergy and Environmental Stewardship in an Agricultural Watershed** (*in preparation*)
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