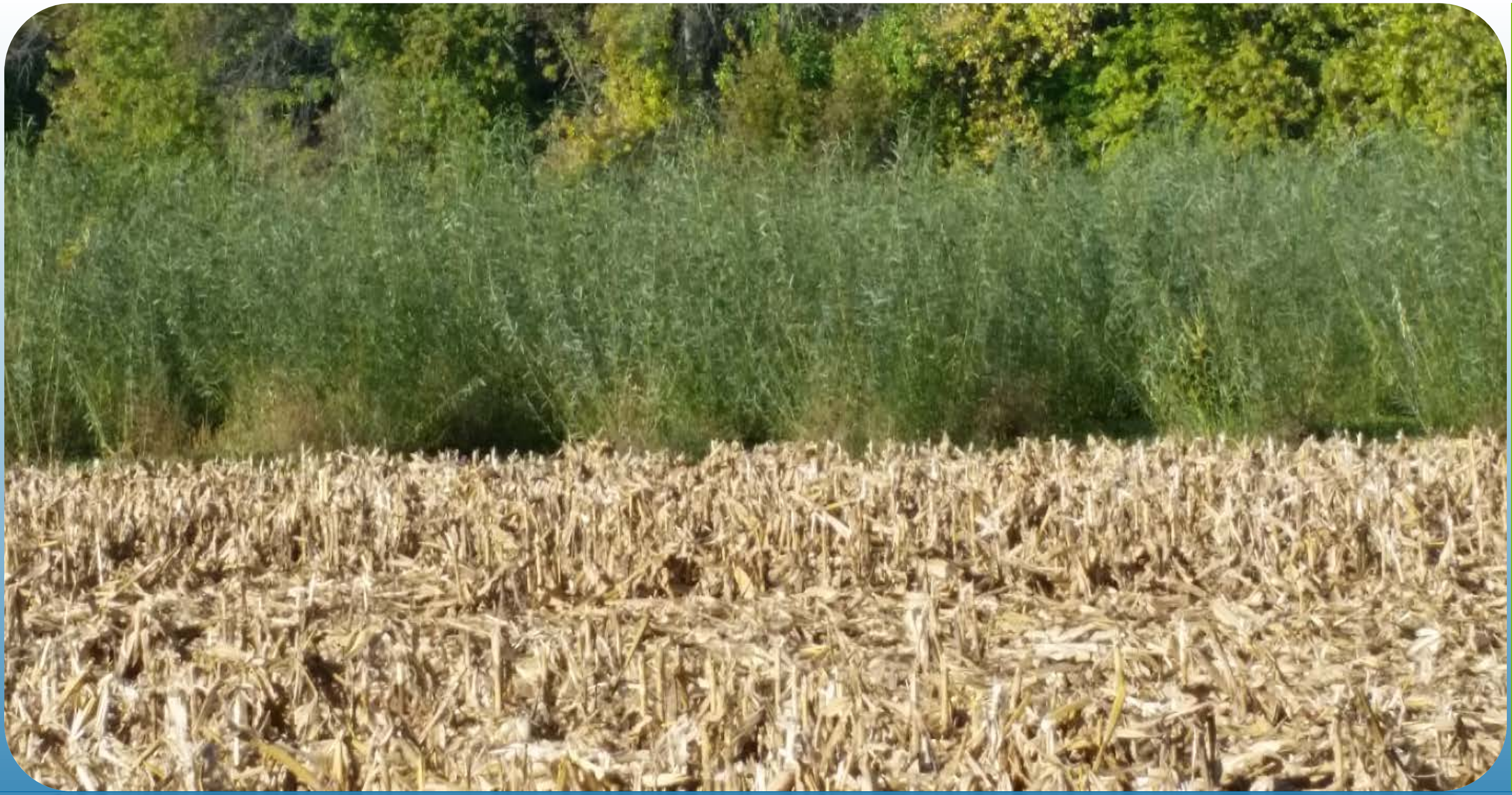
LIGNOCELLULOSIC PLANTS AS BUFFER ZONES



GBEP – IEA Bioenergy Workshop

"Examples of Positive Bioenergy and Water Relationships"

Royal Swedish Academy of Agriculture and Science

Stockholm | August 25-26, 2015

M. CRISTINA NEGRI, HERBERT SSEGANE AND PATTY CAMPBELL
ENERGY SYSTEMS DIVISION, ARGONNE NATIONAL LABORATORY

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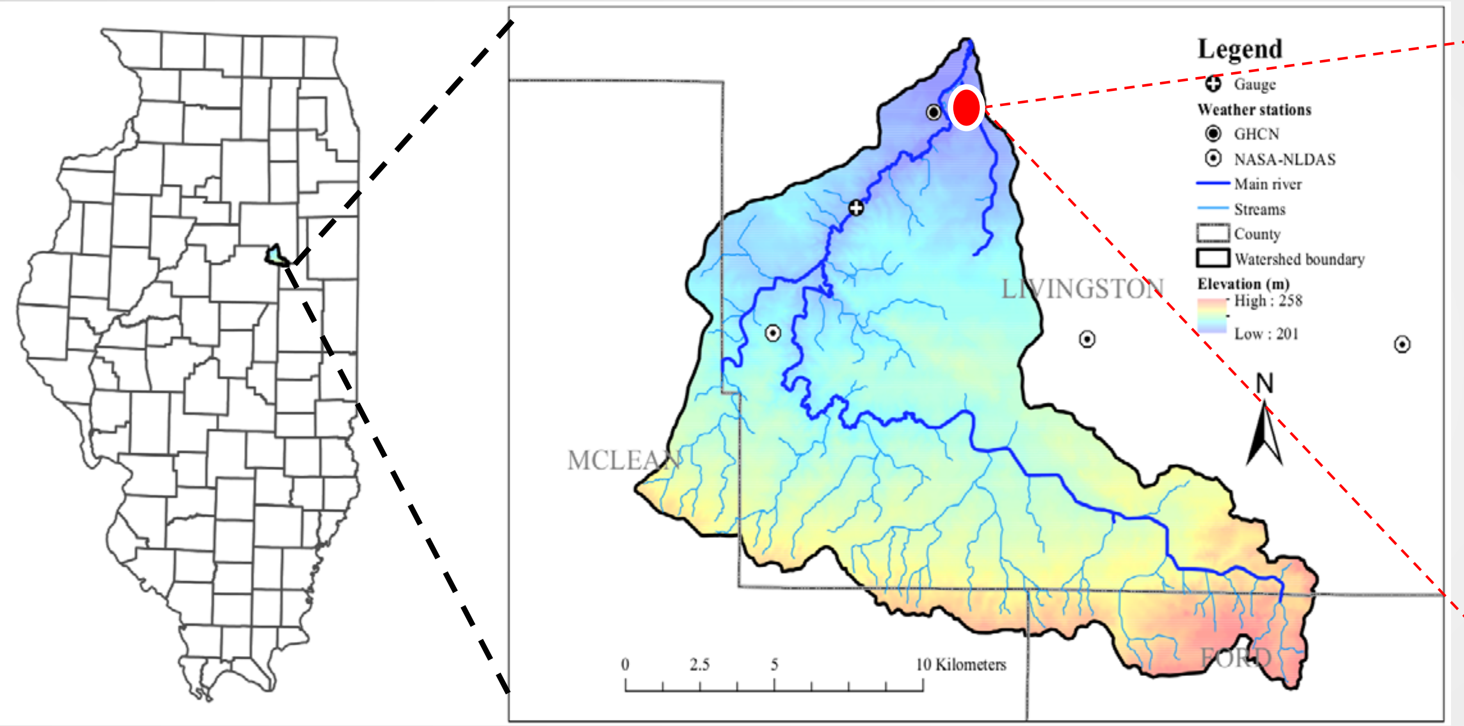
Argonne NATIONAL LABORATORY

PROJECT STATUS AND DESCRIPTION

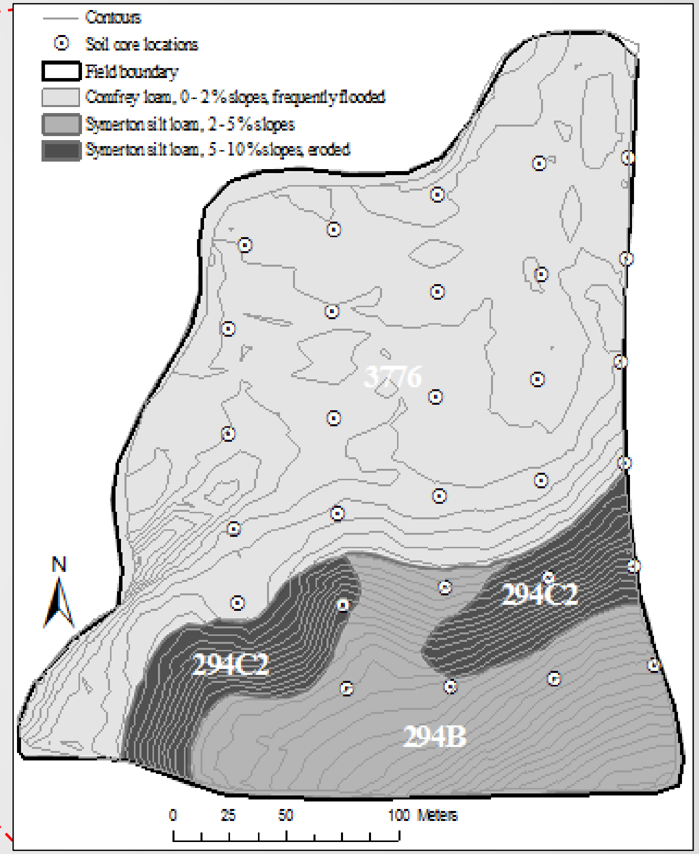
- Project started 2011
- Predicted harvest of willow biomass: winter 2017
- Project includes a field scale trial and a watershed modeling effort.

PROJECT LOCATION: LIVINGSTON COUNTY, IL, USA

Indian Creek watershed, IL



Fairbury site, IL soil map



A STUDY AT THE SCALES AT WHICH IMPLEMENTATION DECISIONS ARE MADE

Ssegane et al., 2015

POSITIVE IMPACTS FOR WATER QUALITY AND AVAILABILITY

- Goal of the project is to achieve a 30% reduction in nitrogen in subsurface flow using a willow buffer, while maintaining acceptable yields and reducing greenhouse gas emissions
- Consumptive water use to be measured and compared with water availability.

MAIN DRIVERS FOR IMPLEMENTATION

- Need to engineer and test ways to build sustainability *by design* into bioenergy systems

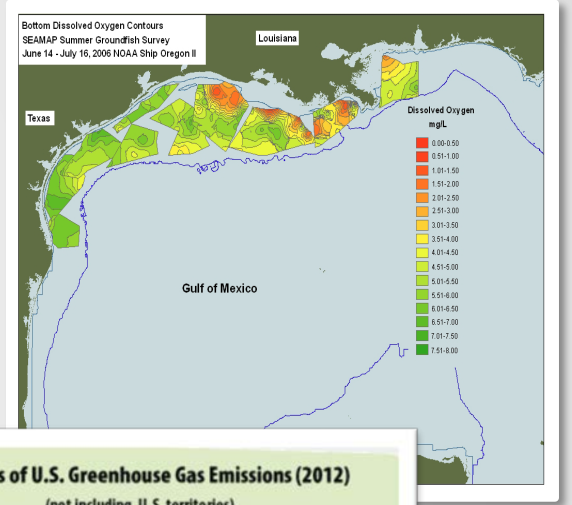
- Need to address water quality concerns
  - Locally - drinking water impaired by nitrate concentrations
  - Nationally - impacts in Gulf of Mexico Hypoxia to be addressed through nutrient management in Mississippi River Basin.

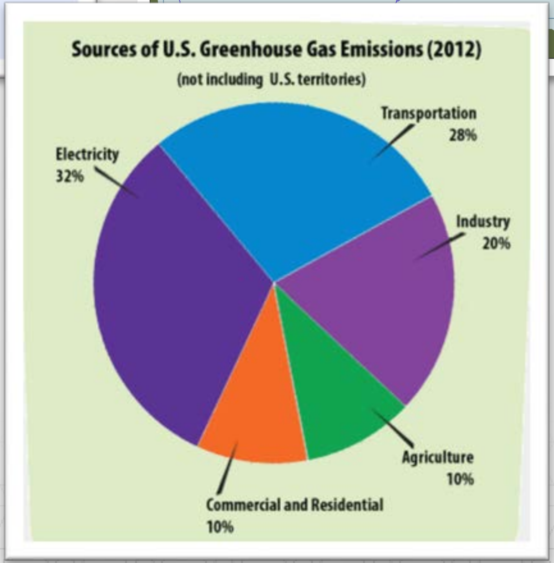
THE BIG PICTURE: AGRICULTURE'S SUSTAINABILITY CHALLENGE

- Providing food, feed, fiber, energy for a growing world population
- Conserving soil, water and biodiversity, and decreasing greenhouse gases
- Providing resilience to a changing climate

E. Detaille, Charge of the 4th Hussars at the battle of Friedland, 14 June 1807 - http://upload.wikimedia.org/wikipedia/commons/1/10 Detaille_4th_French_hussar_at_Friedland.jpg

Source: U.S. Global Change Research Program [http://e360.yale.edu/feature report_gives_sobering_view_of_warmings_impact_on_us/2166/](http://e360.yale.edu/feature)



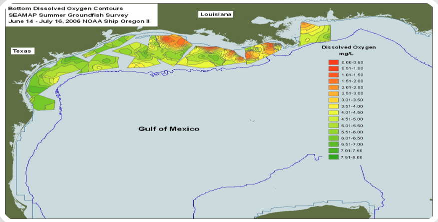


Questions for bioenergy development

- Is there sufficient land?
- Is land for food and conservation impacted?
- Do we have the right crops?
- What are the impacts to water quality and quantity?
- Is there a better way to plan for our resources?

DESIGNING LANDSCAPES TO INCLUDE BIOENERGY

LEVERAGING THE POSITIVE TRAITS OF LIGNOCELLULOSIC BIOENERGY CROPS AND BUFFER FUNCTIONS TO INCREASE SUSTAINABILITY



NUTRIENT LOADINGS

- Exploit deep rooted perennials to capture runoff and subsurface flow in strips and target areas
- Beneficially reuse nutrients lost from other crops to enhance biomass yields

WATER QUANTITY

- Design planting to match water budget
- Preferentially target marginal water

GRASSLAND CONVERSION AND DEFORESTATION

- Sustainably intensify arable land production through resource allocation planning

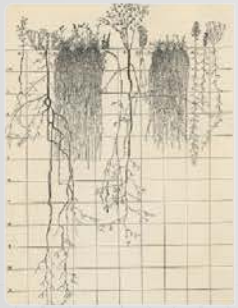
BIODIVERSITY

- Use bioenergy crops as shelter, connectivity and nesting opportunities to support biodiversity

SUSTAINABLE LAND USE INTENSIFICATION AT THE FARM LEVEL

+

+



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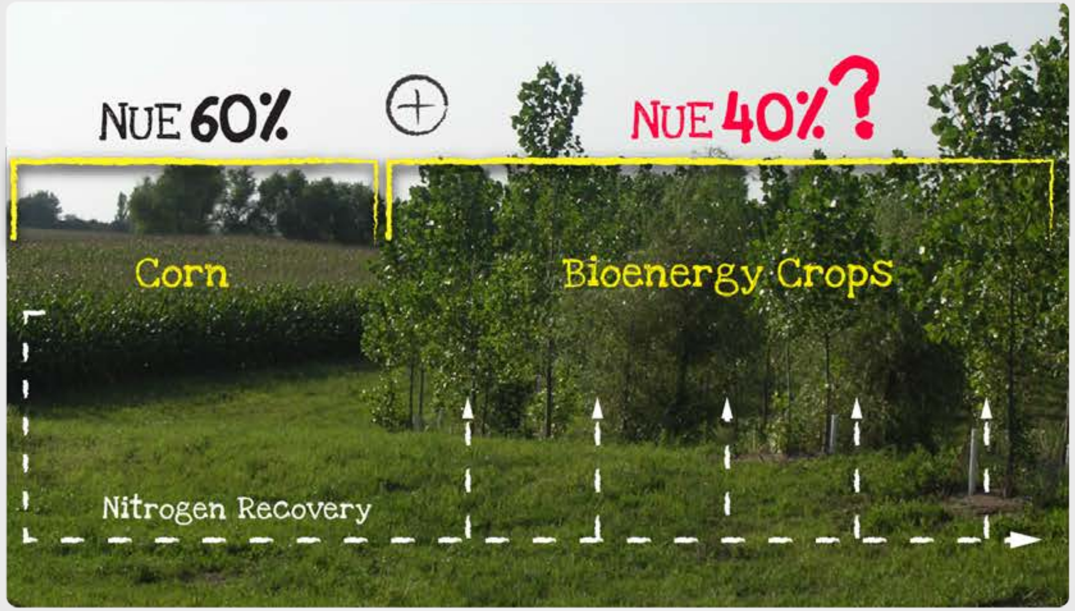
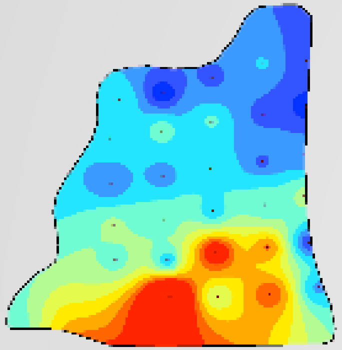
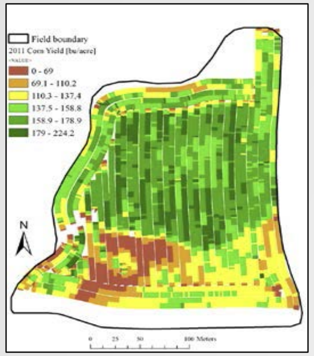


Underproductive land + excess nitrate recycle + deep rooted bioenergy crop = integrated landscape: sustained bioenergy production + environmental services + optimized farm revenue

SUBFIELD VARIATIONS IN SOIL CONDITIONS DETERMINE DIFFERENT ENVIRONMENTAL IMPACTS AND FARM REVENUES





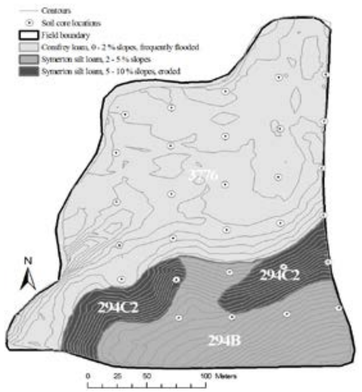
- Not all parts of a field are equally likely to leak nutrients or equally productive
- Areas that are sensitive to grain price and dependent on acceptable loss are candidate to bioenergy production (Bonner et al., 2014)
- Risk reduction (flood, drought) is also an economic consideration

- Finding the sweet spot where it is cost-effective to grow biomass rather than corn/soybean, and where we can target the highest nutrient losses

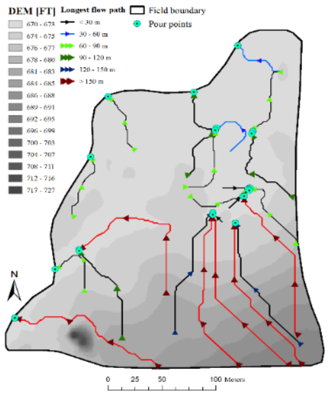
- Dual-use crops and dual payment: paving the way for ecosystem services valuation for economic sustainability.

DESIGNING A BIOENERGY BUFFER

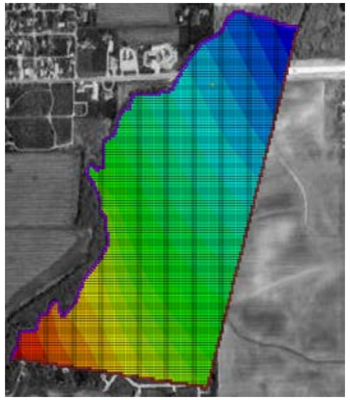
Soil classification



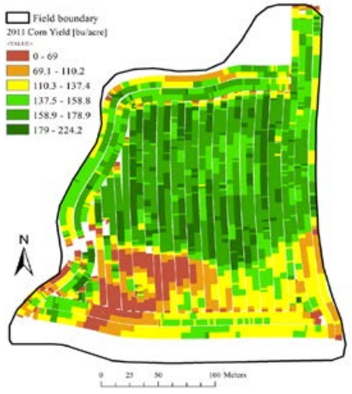
DEM and flow path lengths

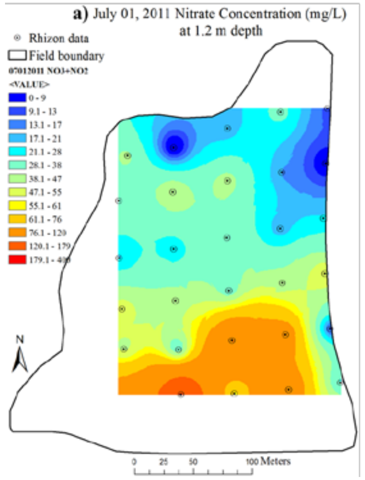


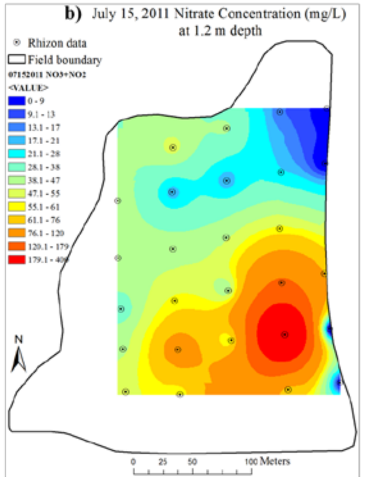
Hydrogeological model

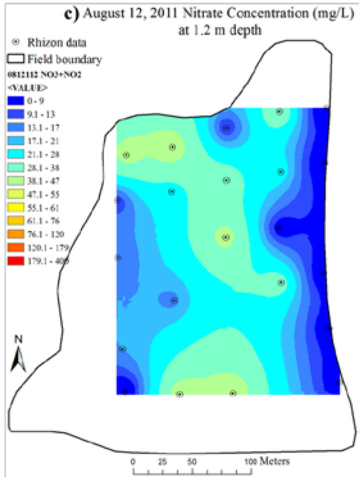


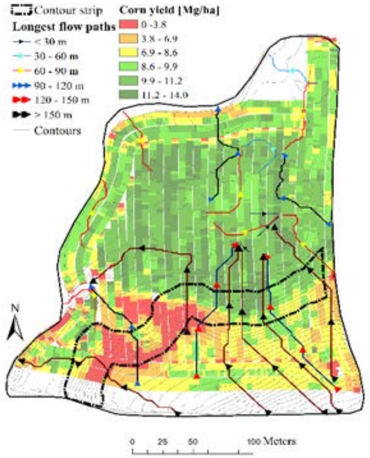
2011 corn yield map











Ssegane et al., 2015

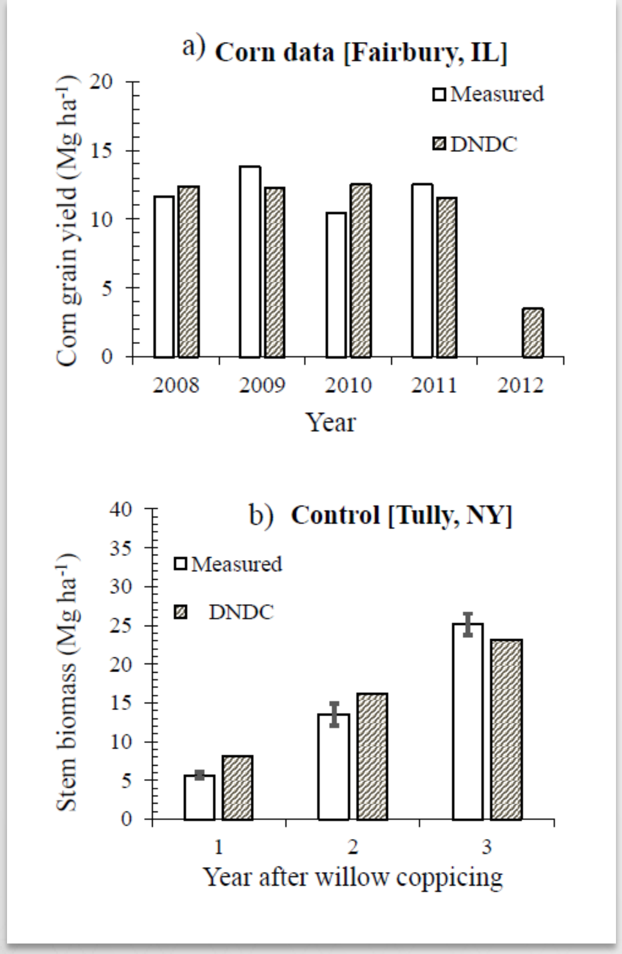
KEY ENABLING FACTORS

- A vision
- A farming community interested in the health of its watershed and receptive to innovation
- Partnership with CTIC, a non-profit conservation organization already in the watershed aggregating the community of farmers around conservation practices.

ENVIRONMENTAL MONITORING

PREDICTED IMPACTS

DNDC MODEL DEVELOPMENT RESULTS: N_2O EMISSIONS, NO_3^- LEACHING AND CROP YIELDS



Simulated average (and standard error) annual yields, leached NO_3, and N_2O emissions at the Fairbury site, IL for 2008 to 2012.

Scenario[a]	Yield	Leached NO_3	N_2O flux
	Mg ha^{-1} yr^{-1}	kgN ha^{-1} yr^{-1}	kgN ha^{-1} yr^{-1}
Corn	10.4 ± 1.7	31.9 ± 4.4	2.2 ± 0.3
Corn / switchgrass	8.7 ± 1.0	11.6 ± 1.6	2.0 ± 0.2
Corn / willow	9.7 ± 0.6	12.5 ± 1.6	1.9 ± 0.2
% reduction[b]	---	61.0 ± 6.2	5.5 ± 3.1
	---	59.3 ± 4.0	10.8 ± 2.6

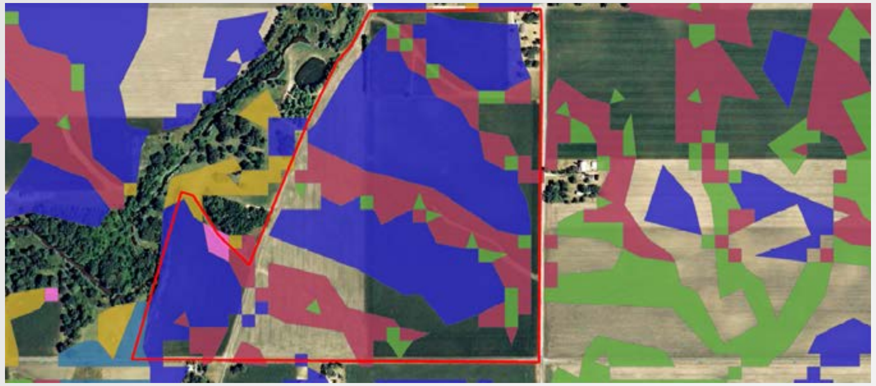
[a]Corn scenario is the continuous corn while corn/switchgrass and corn/willow scenarios replace only corn in the buffer with one of the energy crops. The yields under scenarios two and three are for the energy crops in the buffer. The NO_3 and N_2O are area weighted values for the entire field and thus include areas still under corn.

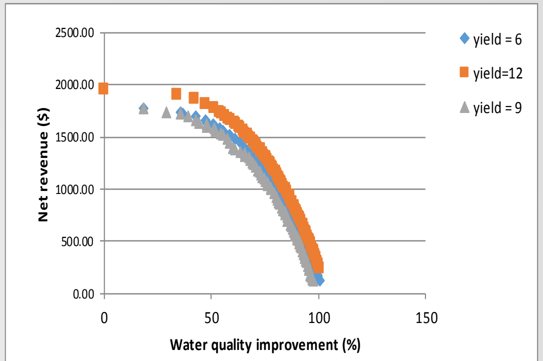
[b]Top values are percent reductions when the buffer is under switchgrass and the bottom values under willow

From Ssegane et al., 2015

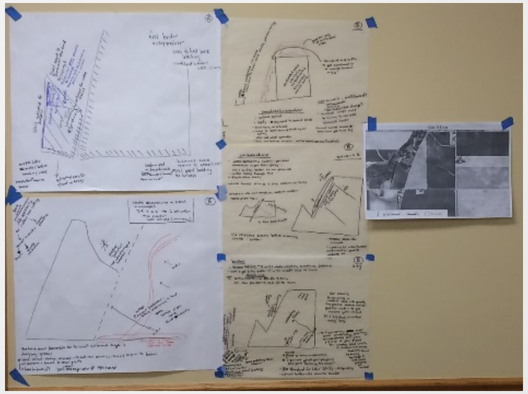
CREATING AN ENGAGED COMMUNITY OF STAKEHOLDERS GENERATES PRACTICAL SOLUTIONS

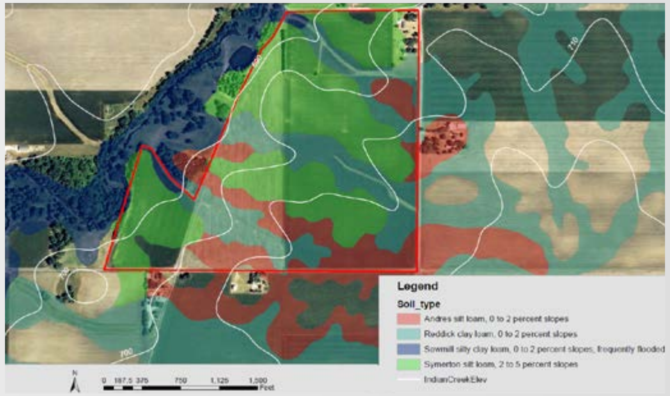
Field Conditions





Gopalakrishnan et al., 2011





Soil and Elevation Map

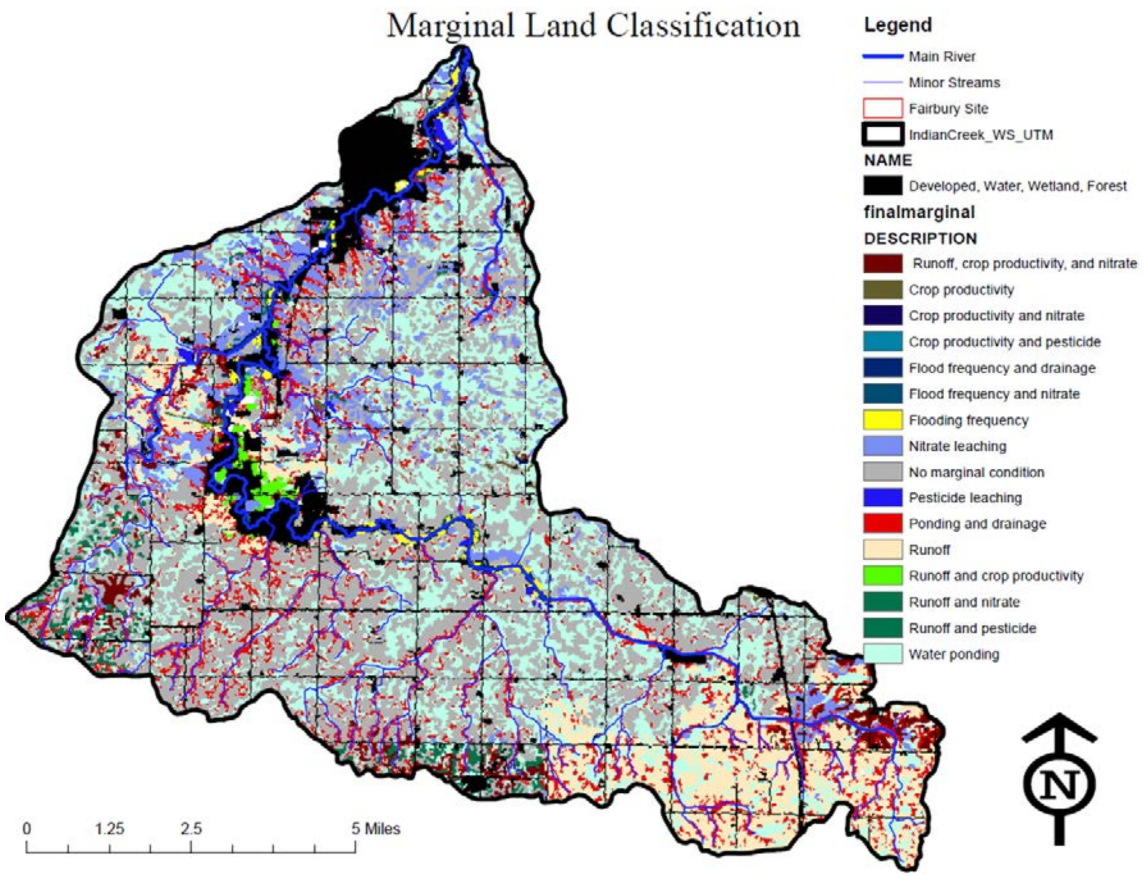
In collaboration with the University of Michigan

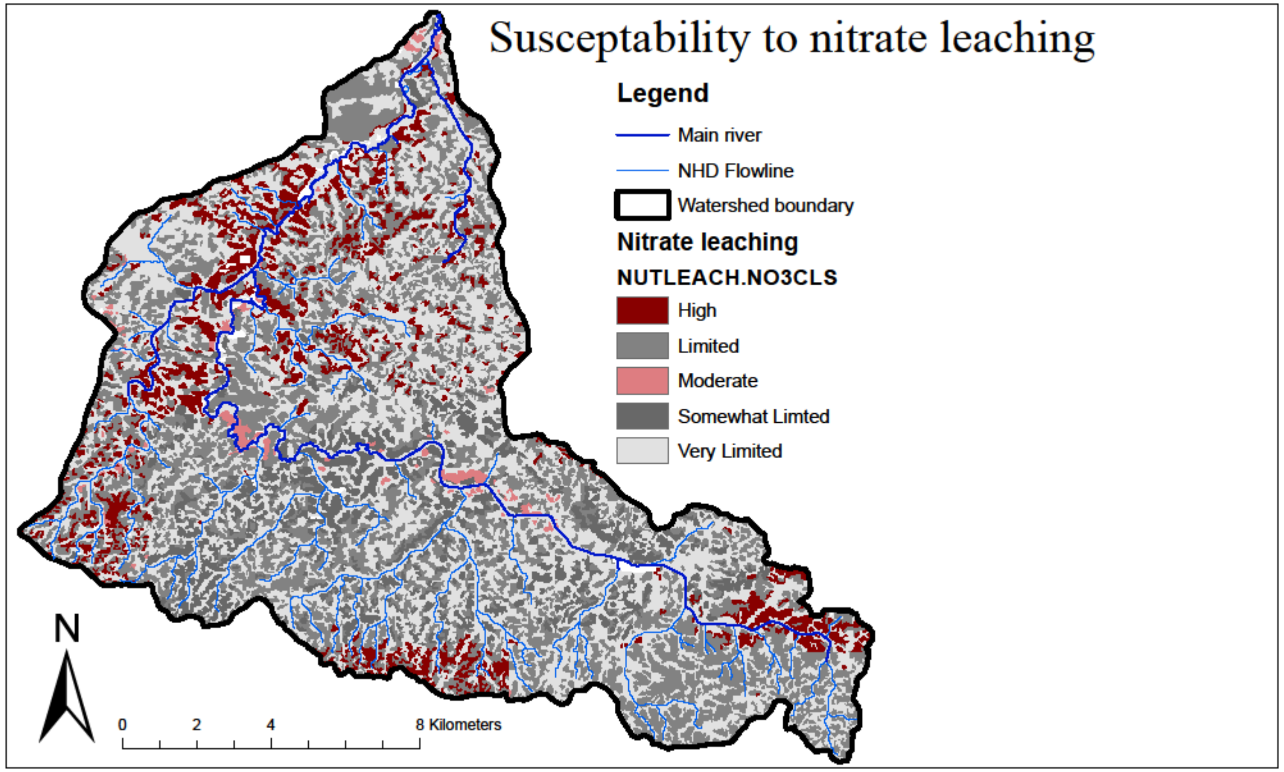
CHALLENGES AND POTENTIAL FOR SCALING UP

- Poor soils are poor soils….
- Management practices for crops need to be revisited (e.g. weed management)
- Need to find “cheap” ways to design and monitor
- Markets for biomass need to be established
- Great deal of technical assistance is needed to scale up
- USDOE is examining proposals for full watershed demonstrations
- Significant interest from industry, farmers, and regulators can be leveraged.

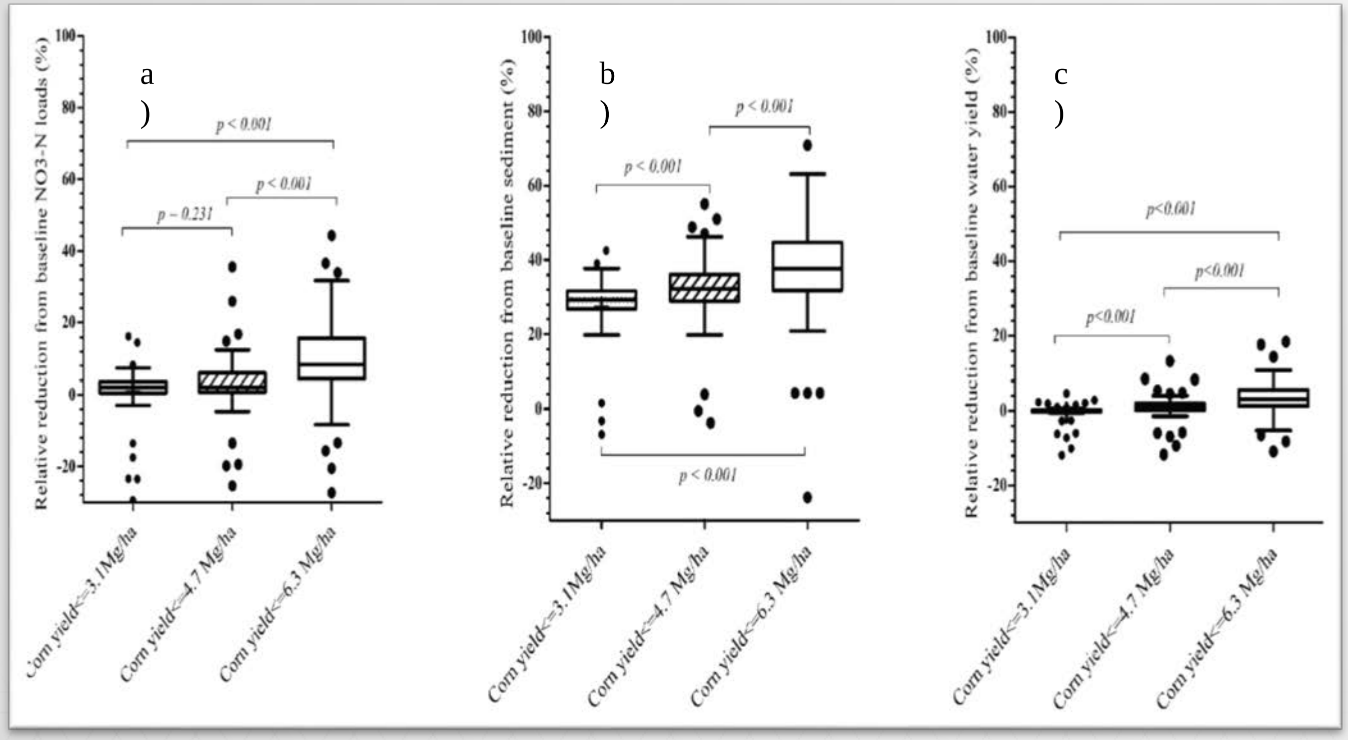
SCALE UP TO WATERSHED

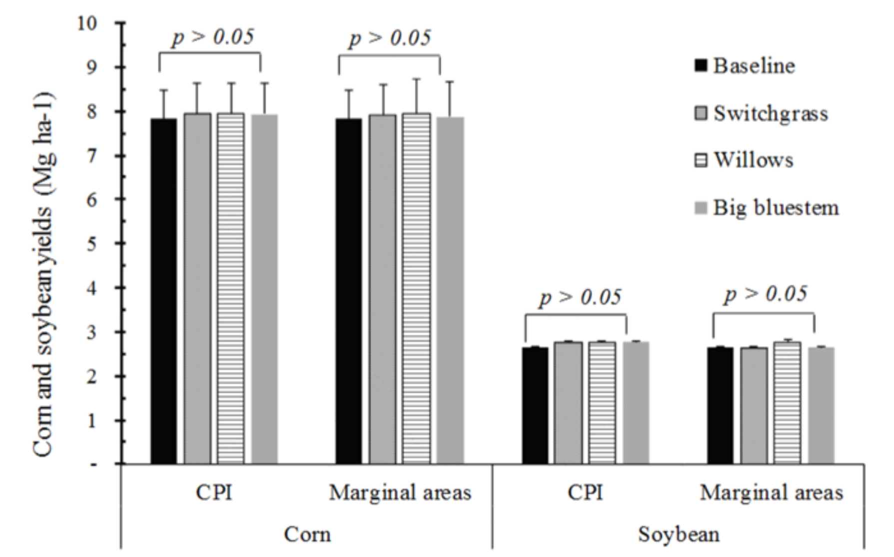
LAND PROPERTIES ARE A BASIS FOR WATERSHED DESIGN

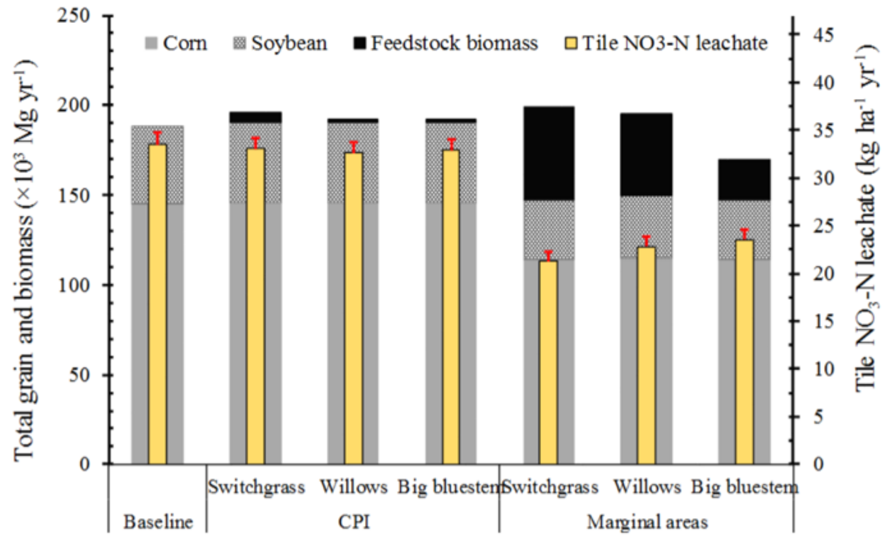




CROP PRODUCTION AND WATER QUALITY PROJECTIONS IN THE WATERSHED







Hamada et al., 2015

SUMMARY

- Ongoing work provides primary data on the system's performance, modeling has shown landscape design to be potentially beneficial to water quality
- Not all buffers are created equal: we need to understand their potential benefit and ideal placement
- Available datasets can help in targeting land for bioenergy and ecosystem services
- Current management practices need to be revisited (e.g. weed management)
- Work needs to be done to further design on farm logistics
- Direct involvement of the farming community is critical.

ACKNOWLEDGEMENTS

- Our student interns from 2011 to 2015!
- Paul Kilgus
- Terry Bachtold –Livingston County SWCD
- Eric McTaggart, Livingston County USDA-NRCS
- Conservation Technology Information Center
- Gayathri Gopalakrishnan
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- The Indian Creek Watershed Project Leadership and Sponsors
- Eric Rund, Harold Reetz, and many others who provide realistic input
- Kristen Johnson, Alicia Lindauer, Mark Elless, Alison Goss Eng and Max Broad - BETO.

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SELECTED PUBLICATIONS

Ssegane, H., M. C. Negri, J. Quinn and M. Urgun-Demirtas (2015). **Multifunctional Landscapes: Site Characterization and Field-Scale Design to Incorporate Biomass Production into an Agricultural System.** *Biomass and Bioenergy 80: 179-190*

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