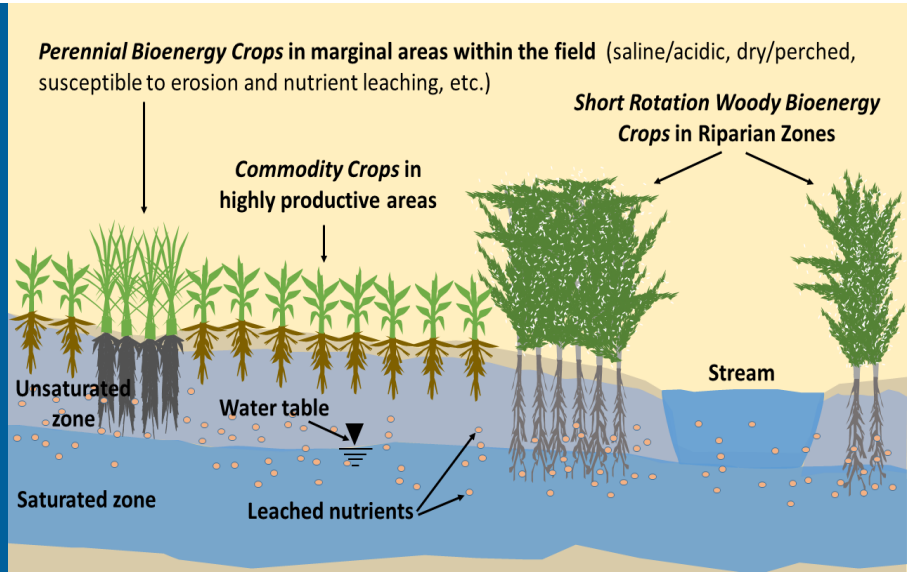
DOE BIOENERGY TECHNOLOGIES OFFICE (BETO)

2019 PROJECT PEER REVIEW

Argonne NATIONAL LABORATORY

WBS 4.2.2.10: BIOMASS PRODUCTION AND NITROGEN RECOVERY



Source: Cacho et al. 2017

M. CRISTINA NEGRI
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Environmental Science Division
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March 6, 2019

GOAL STATEMENT

To bolster cost-competitiveness of bioenergy through the valuation of ecosystem services (ES), by investigating ways to integrate bioenergy buffers into the agricultural landscape and evaluating the associated ecosystem services and the comprehensive value generated [performance advantaged feedstock].

Project supports BETO's sustainability platform goal (Sustainable system design) of **validating case studies** of feedstock production systems through a combination of modeling and analysis, field research and evaluation.

Its results can **promote farmer adoption** of sustainable bioenergy crops, while improving water quality, reducing greenhouse gas emissions, and providing pollinator and other wildlife habitat.

QUAD CHART OVERVIEW

Timeline

- Project start date FY2011
- Project end date 9/30/2019
- Percent complete 80%

	Total Costs Pre FY17**	FY 17 Costs	FY 18 Costs	Total Planned Funding (FY 19-Project End Date)
DOE Funded	$3,180 K	$630K	$565K	$670K

Barriers addressed

Strategic Analysis and Crosscutting Sustainability

At-E. Quantification of Economic, Environmental, and Other Benefits and Costs

At-F. Science-Based Methods for Improving Sustainability

At-H. Consensus, Data, and Proactive Strategies for Improving Land-Use Management

Objective

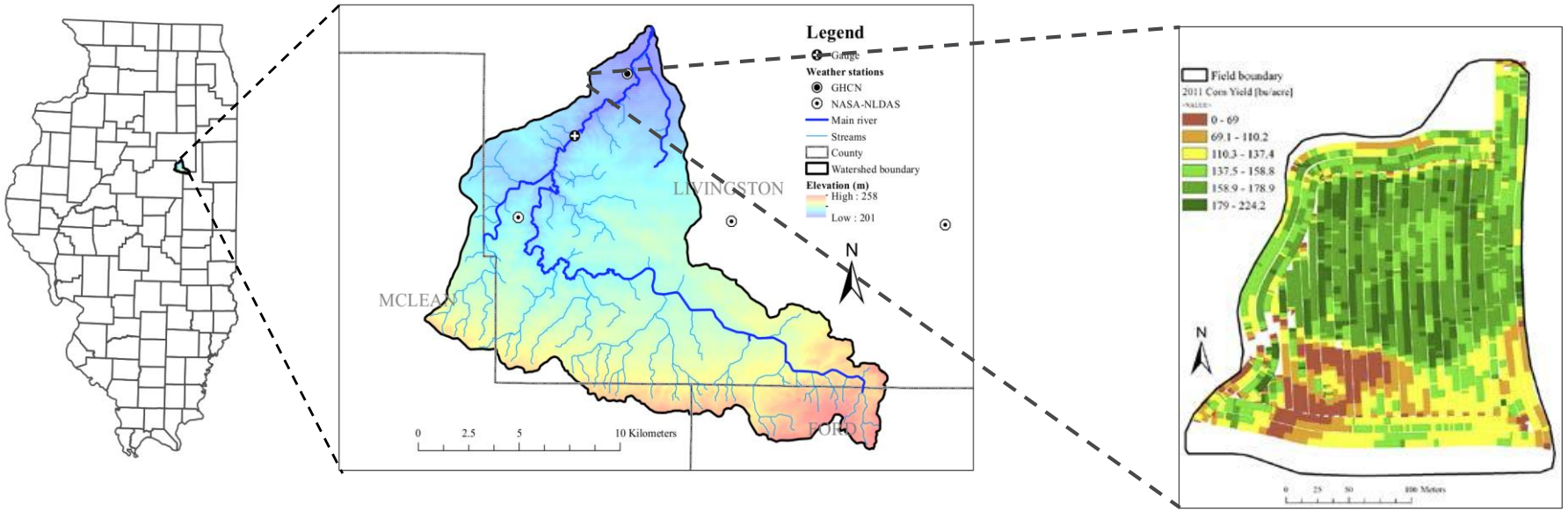
To investigate the integration of bioenergy buffers into the agricultural landscape and evaluate the associated ecosystem services and comprehensive economic value generated.

End of Project Goals

- Bolster cost-competitiveness of bioenergy through the valuation of ecosystem services (ES)
- Field demonstration of ES (Nitrate reduction 30%)
- Watershed modeling and scaling up of ES
- Techno-economic analysis (with INL) assessing farm economics and ES benefits

1 - PROJECT OVERVIEW

- Design a bioenergy landscape to produce environmental services, scaling up from farm to watershed
- Leverages strengths of bioenergy crops to address concerns with current agricultural system through holistic resource management – **focus on N recovery by deep rooted perennials**
- Provides a different economic envelope including both crop production and ecosystem services and compares to current conservation alternatives – improves cost competitiveness of bioenergy



2 – APPROACH (MANAGEMENT)

Critical success factors:

- Cost-effectiveness of data collection
- Identify value to farmers, biorefineries and to ecosystem services payers
- Identification of viable end use markets for biomass and for ecosystem services (ES)
- Identification of acceptable economic conditions

Progress measurement:

- Quality and extensiveness of field data collection, QA/QC
- Milestone tracking
- Go/No-go decision points to redirect and assess project direction
- Monthly, quarterly reporting
- Periodic team meetings including collaborators

Interfaces:

- Collaboration with colleagues at INL for techno-economic analysis
  - INL: field operations optimization
  - ANL: ecosystem services valuation

Team Structure:

- Principal Investigator M. Cristina Negri – overall project direction
- Co- PI John Quinn– day-to-day operations leadership, QC, field, hydrogeology
- Lab Manager Patty Campbell – lab analyses, sample management, interns, field
- Field Manager Colleen Zumpf – field planning and operations, interns, UIUC liaison
- Modeler Jules Cacho – analysis of watershed impacts and saturated buffer, field
- Economist Shruti Mishra – analysis of ecosystem services valuations

Team Collaborators (selected):

- University of Illinois Urbana-Champaign (UIUC): field and technical assistance
- University of Michigan: pollinator modeling
- University of Iowa: Ecosystem services valuation/economics
- State University of New York/ESF: Willow technical assistance, willow economics
- INL: Logistics analysis, biomass analysis and testing, Hypoxia workshop collaboration and TEA
- ANL GREET team (C. Canter) for LCA.
- ORNL: Hypoxia Workshop collaboration
- County NRCS, SWCD, and UIUC Extension: farmer engagement support
- NRCS, other researchers: collaboration on path for approval of bioenergy buffer as a conservation practice
- Illinois Nutrient Reduction Loss Strategy (NRLS): participation and presentation at NRLS events
- Vermilion Headwaters Watershed Partnership: committee membership and participation

2 – APPROACH (TECHNICAL)

Metrics:

- ✓ Target: Achieve 30% N-NO_3 reductions based on current knowledge (Smith et al., 2013*)

- Go/No-go Decision Points:
  - ✓ FY15 - based on growth, propose an additional year of project
  - ✓ FY16 – Assess completeness of field data and plan for additional collection as needed
  - ✓ FY17 – A procedure for identification of biomass as conservation practice is found.

Proof of concept (FY10)

Field study (FY11-19)
Measure yield and environmental indicators

Small watershed modeling (FY13-18)

- Identify "marginal" land
- Target for bioenergy design (FY14-16), Analyze impact

Develop system framework for scale up to region (FY18-19)

- Develop Ecosystem Services quantification and valuation approach (FY17-18)
- Conduct TEA (FY16-19) and LCA (FY17-19) based on watershed model and field data

*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.

3 – TECHNICAL ACCOMPLISHMENTS/ PROGRESS/RESULTS

- *Subsections will summarize*
  - ***Primary field study findings***
  - ***Landscape design (modeling)***
    - ***Ecosystem Services (ES) valuation***
    - ***Lifecycle Analysis (LCA)***
    - ***Techno-economic analysis (TEA)***
  - ***Path for approval of bioenergy crops as a conservation practice***
  - ***Framework integration***

FIELD STUDY FINDINGS

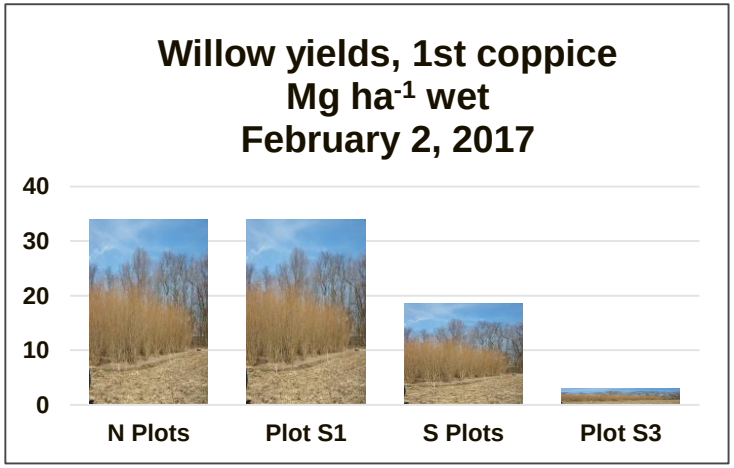
2013

2014

2015

Study site near Fairbury, IL
6.5 hectare, non tile drained, Corn-soy

Winter 2017



FIELD MONITORING INFRASTRUCTURE

Buried Nitrate collectors

Water table monitoring

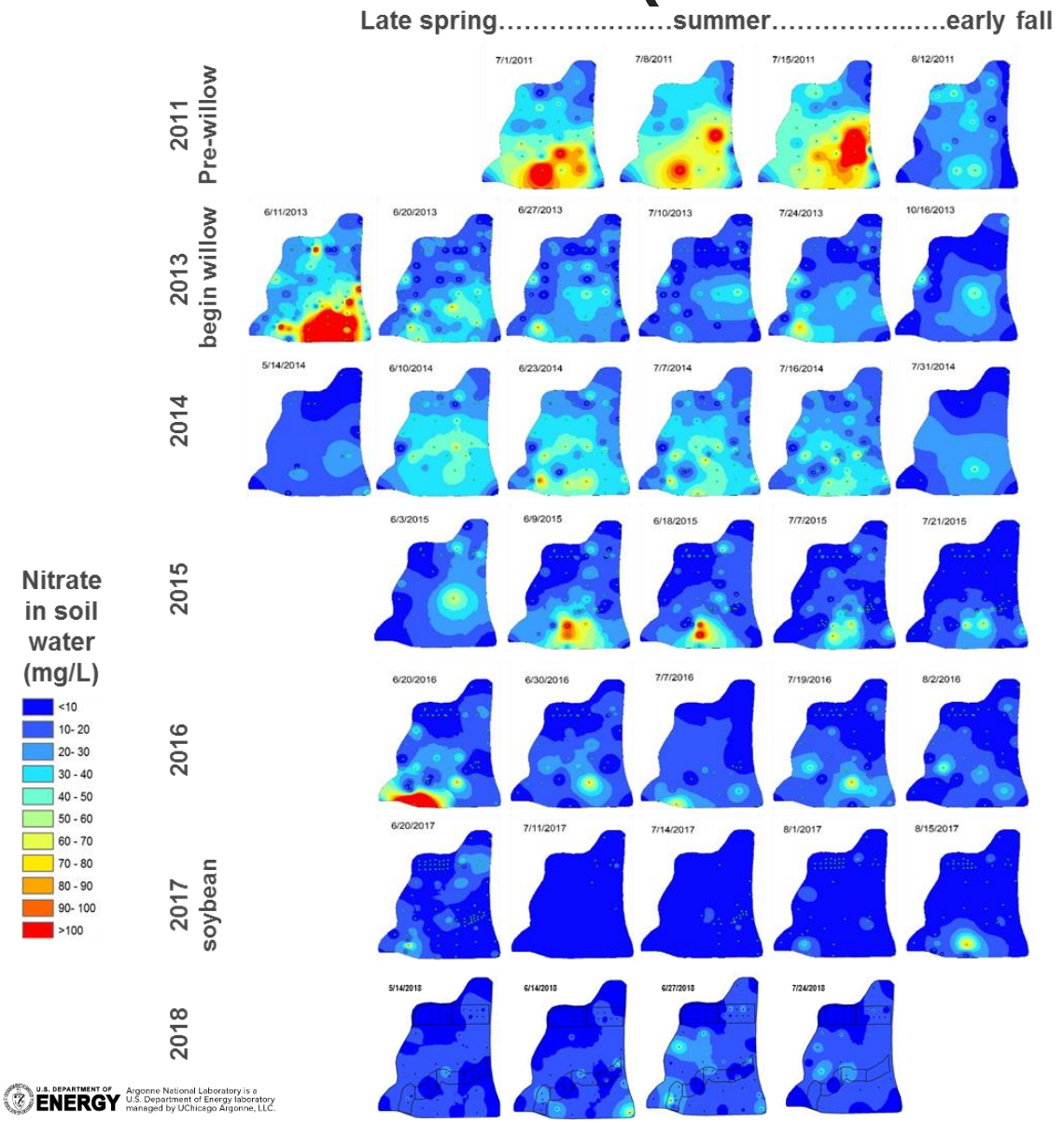
Static GHG flux chambers

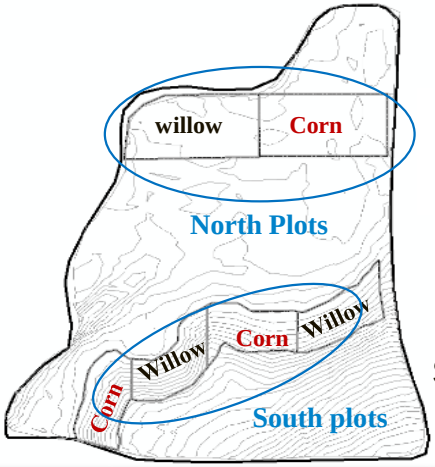
Crop growth monitoring

Profile soil moisture monitoring
[10, 30, 60, 100, 120 cm depth]

Soil-water sample collectors

RESULTS: CHANGES IN SOIL WATER NITRATE CONCENTRATION (AT 5 FT BGS)

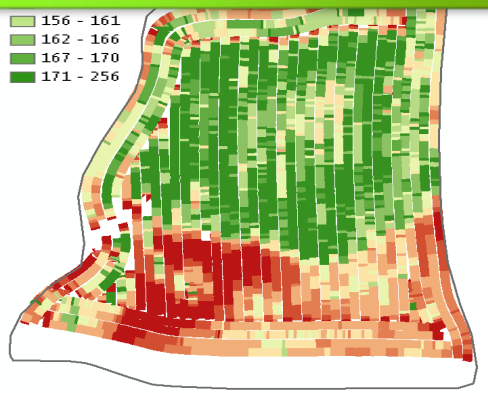




Fertile soil

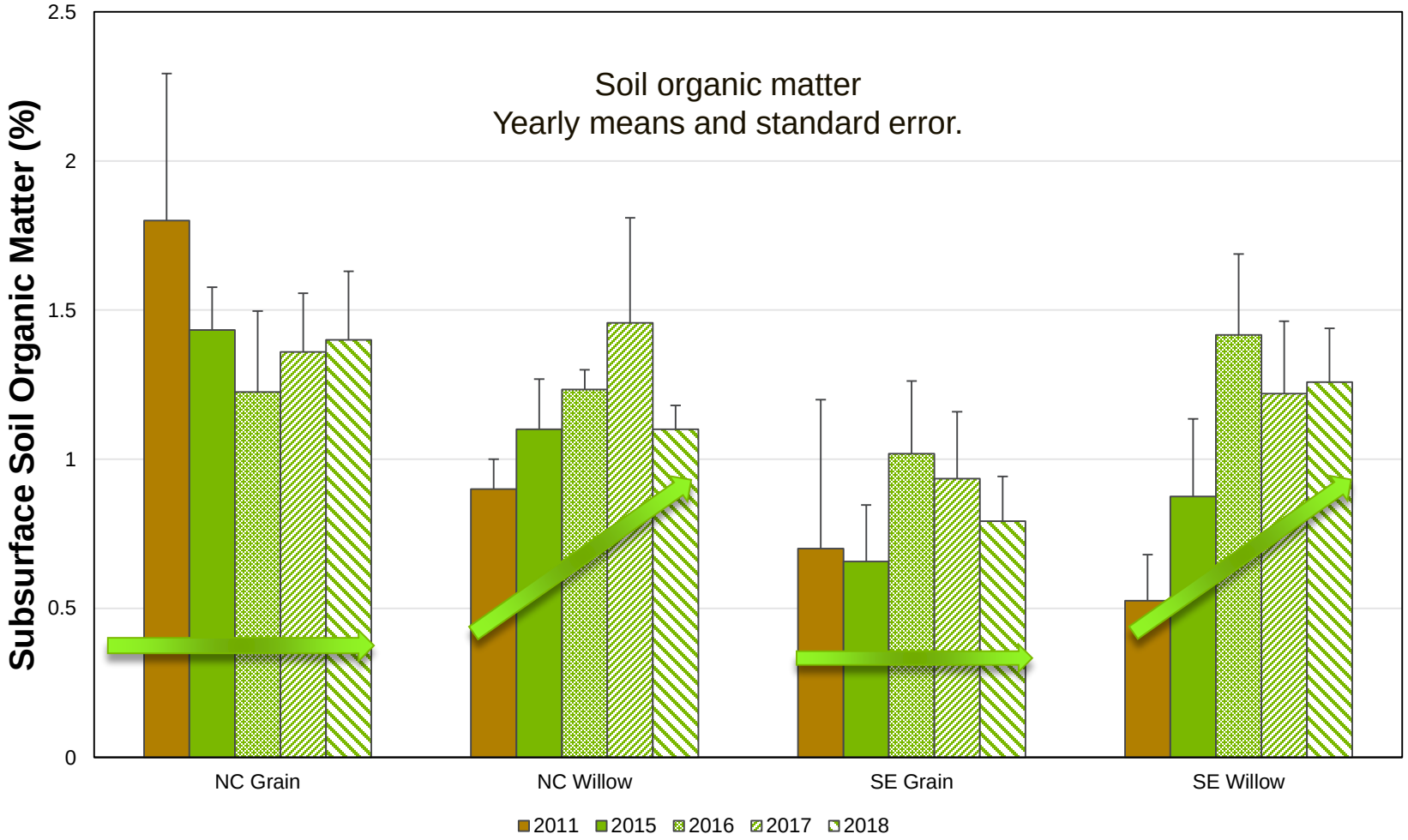
Marginal soil

The Goal to reduce leached nitrate by 30% compared to BAU was met in 2015.



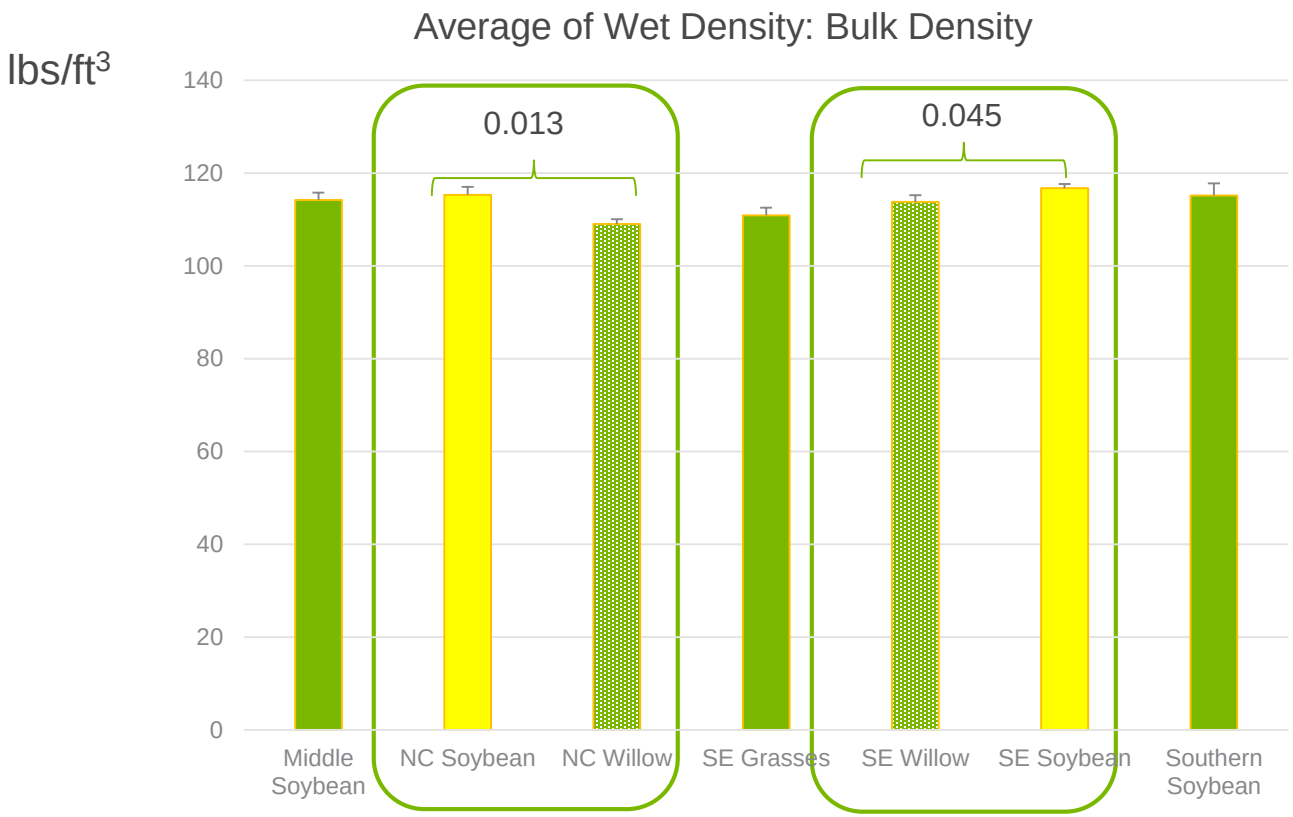
Yield map: areas of **low** (RED) and **high** (GREEN) yields (bu/ac). Low yield areas coincide with high nitrate losses.

RESULTS: SOIL ORGANIC MATTER



Topsoil samples collected from the top 6 inches of a 4-foot core (not shown), subsoil samples from the bottom 6 inches of a 4-foot core. Zumpf et al. (2017)

SOIL BULK DENSITY

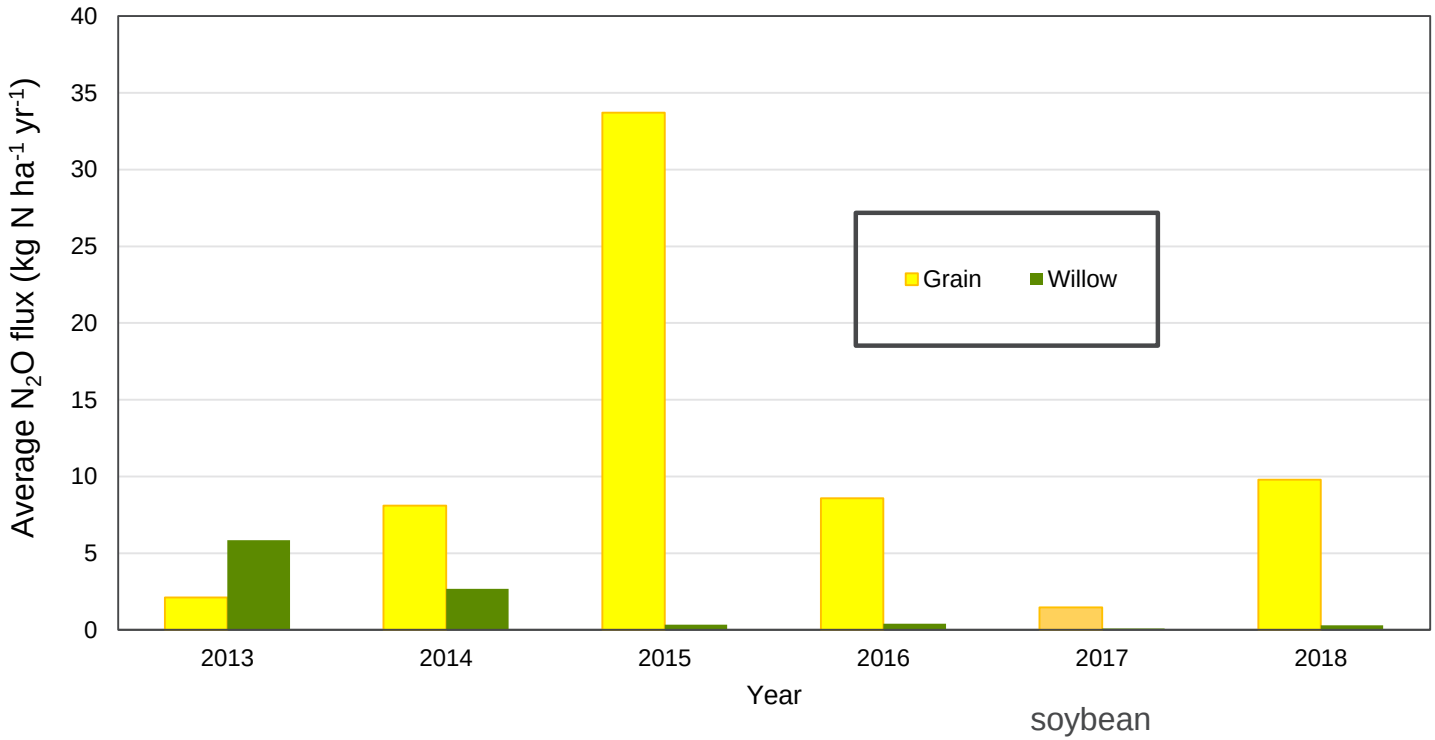


Troxler 3440 moisture-density gauge on June 14th and June 15th, 2017

Significantly lower bulk density under willow than soybean

RESULTS: GREENHOUSE GAS FLUXES

- N_2O in willow plots – significant decline after plants established.
- N_2O in corn/soybean plots – higher, more uniform, with spike in 2015 attributed to a wet year.



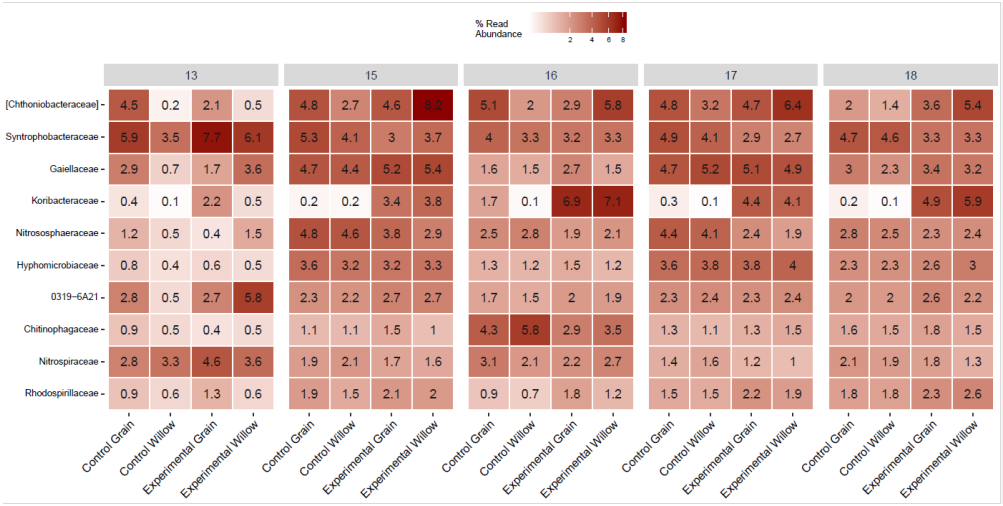
RESULTS: SOIL MICROBIAL DIVERSITY

Interest:

- Microbial diversity is a good measure of soil health
  - Functional groups of bacteria and archaea: role in nutrient cycling
- Interested in how microbial community is impacted by a variety of factors:
  - Crop cover and land management changes
  - Landscape position (topography and soil type)
  - Soil chemical parameters
  - Time
  - Soil depth

Approach:

- Metagenomic analysis: 16S rRNA
  - data from 2011 (pre-willow) to 2018 – analysis in progress.



10 Dominant taxa at the family level

Koribactereraceae - 10x more abundant in the marginal land plots
Nitrososphaeraceae - 2x more abundant in the non marginal plots
This is a general overview of dominant taxa by year
Further analysis pending the collection of the entire dataset.

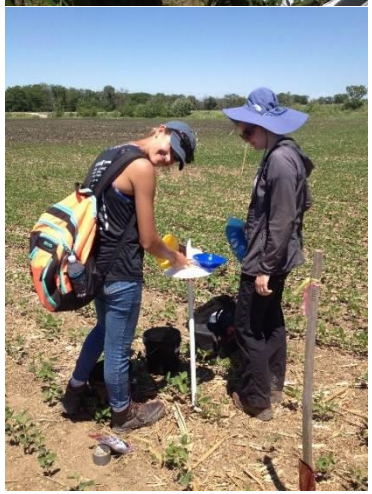
RESULTS: CANOPY INSECT BIODIVERSITY

ANCILLARY SERVICE

Interest:

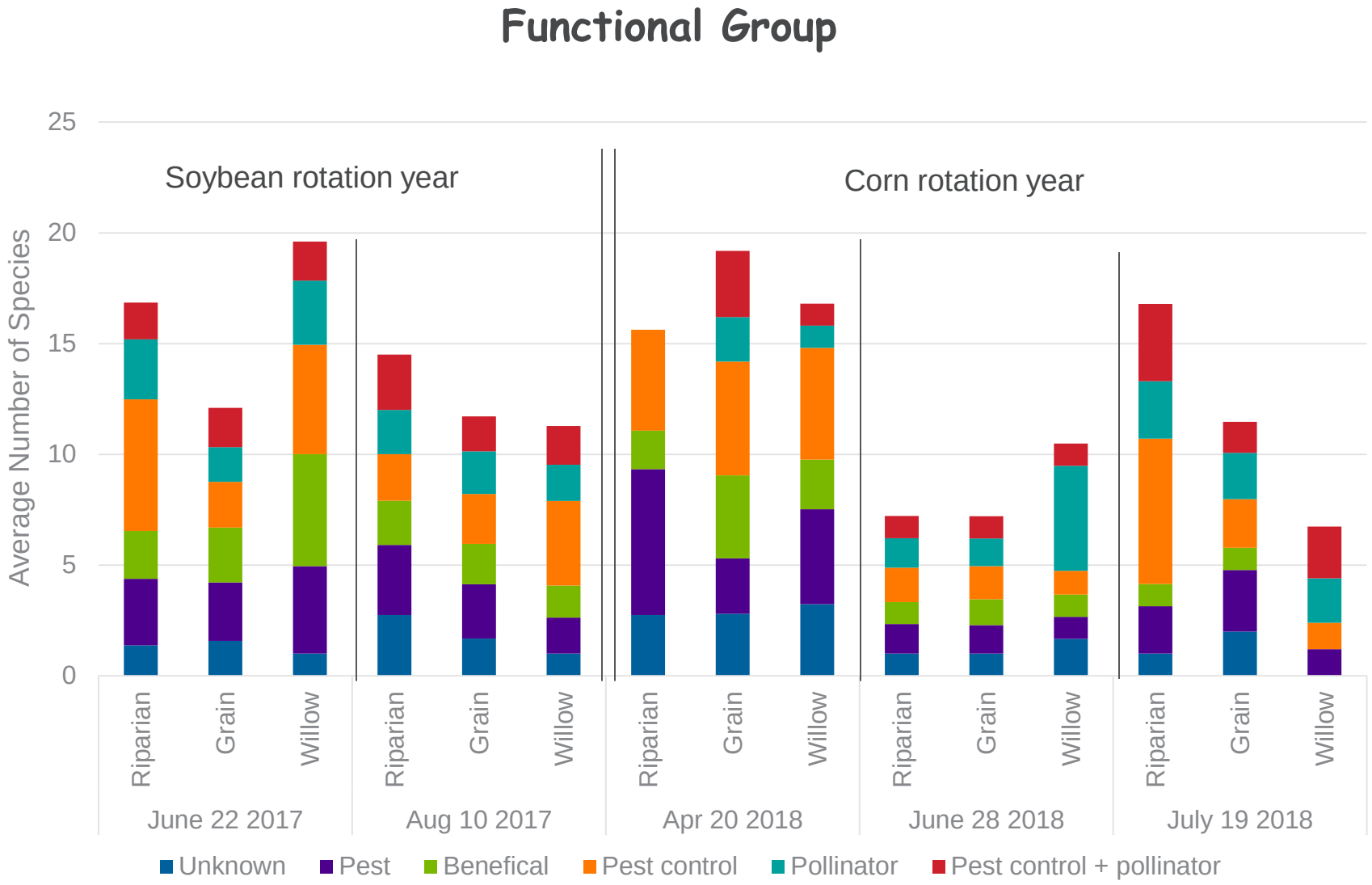
- Insects can play important roles in providing valuable services such as pollination and pest control
- Multiple land cover can provide beneficial but also negative functions

Pollinator Traps



Double barrier Pitfall Traps

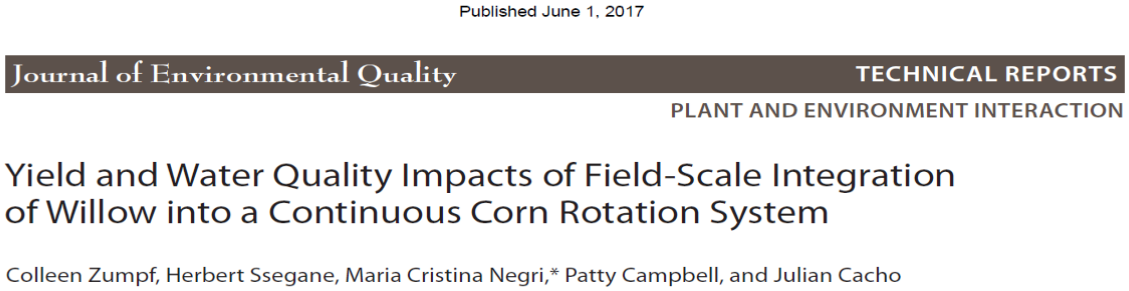
RESULTS: CANOPY INSECT BIODIVERSITY



SUMMARY OF FIELD DATA

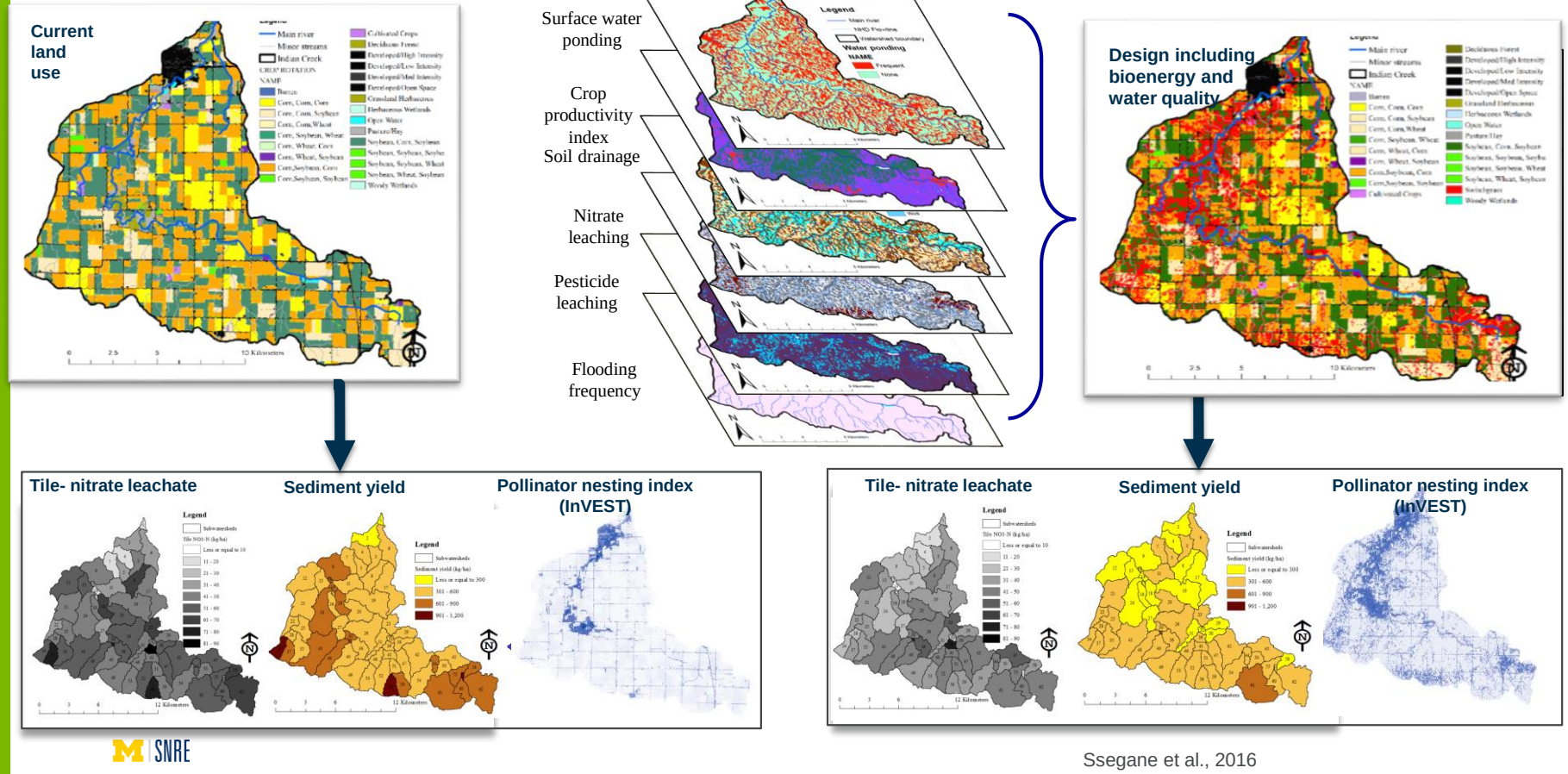
Multifunctional landscape design

- Significantly reduces nitrate in soil water
- Substantially improves the system's N use efficiency, minimizes nutrient loss, improves water quality.
  - Surpassed goal of 30% nutrient loss reduction
  - Greatly reduced N_2O GHG emission in bioenergy plots
- Has subsoil carbon sequestration potential, decrease soil bulk density
- Potential benefits to pollinators, biodiversity and soil microbe diversity *being evaluated*



ECOSYSTEM SERVICES VALUATION

Previous work - Watershed design for ecosystem services on "marginal lands"



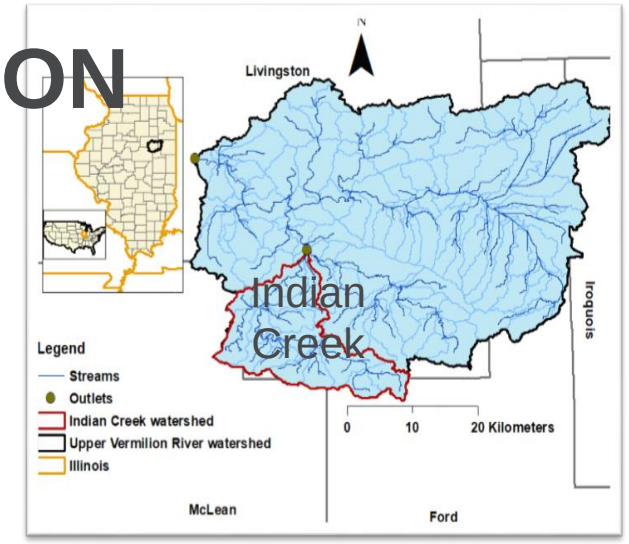
Ssegane et al., 2016

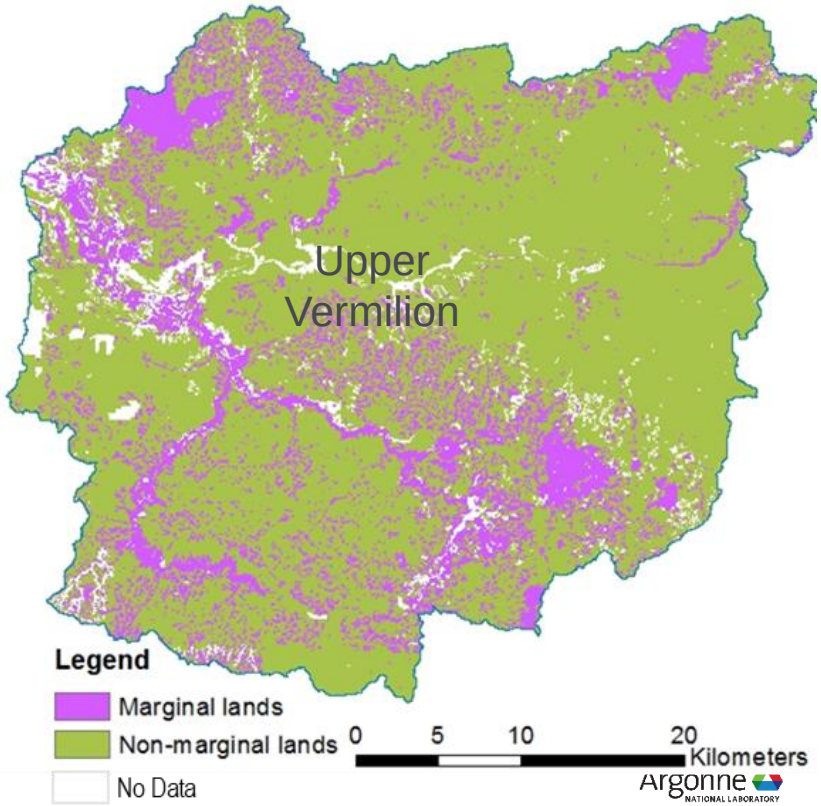
Ssegane H. and M C. Negri (2016) **An Integrated Landscape designed for Commodity and Bioenergy Crops in a Tile-drained Agricultural Watershed.** Journal of Environmental Quality, published May 31, 2016, DOI:10.2134/jeq2015.10.0518

VERMILION RIVER VALUATION

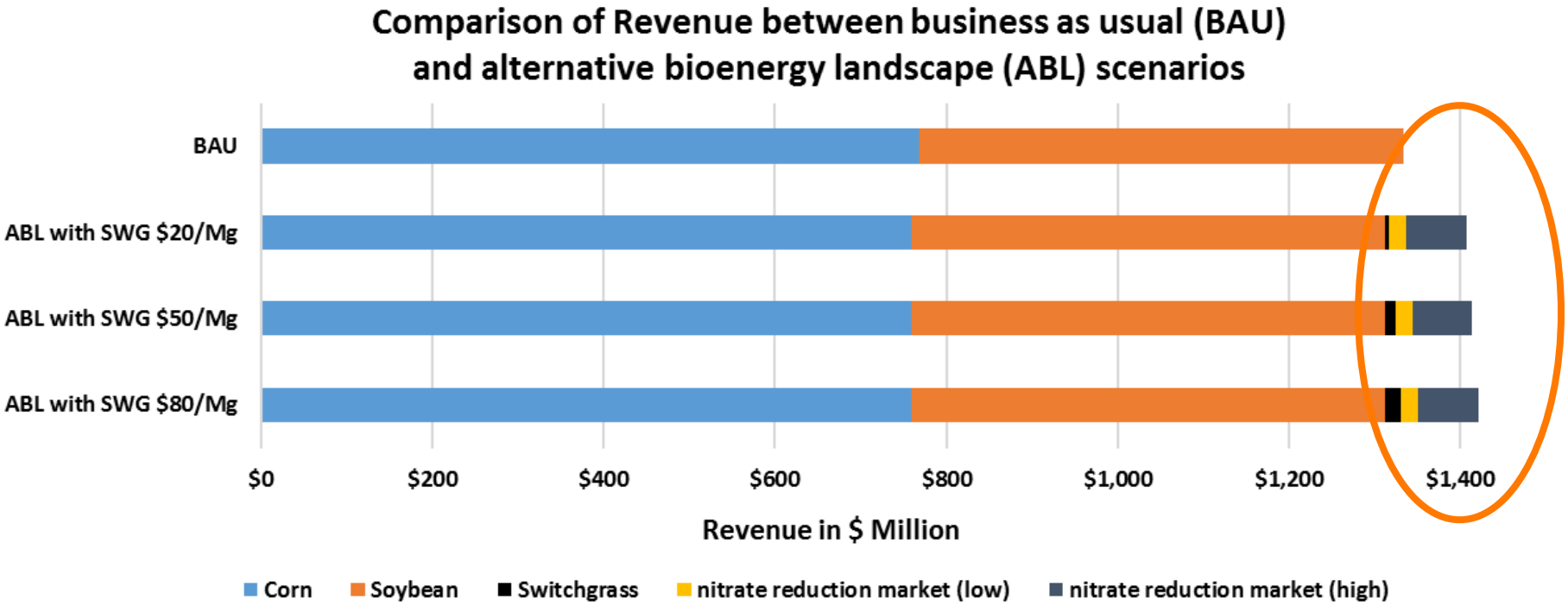
- Assessed basin's value for nitrate loss reduction, erosion/sedimentation, GHG, water-based recreation, wildlife viewing, hunting, and pollinator services
  - when marginal lands converted to bioenergy crops
  - Benefit Transfer Method

- Journal paper in press (Global Change Biology Bioenergy)





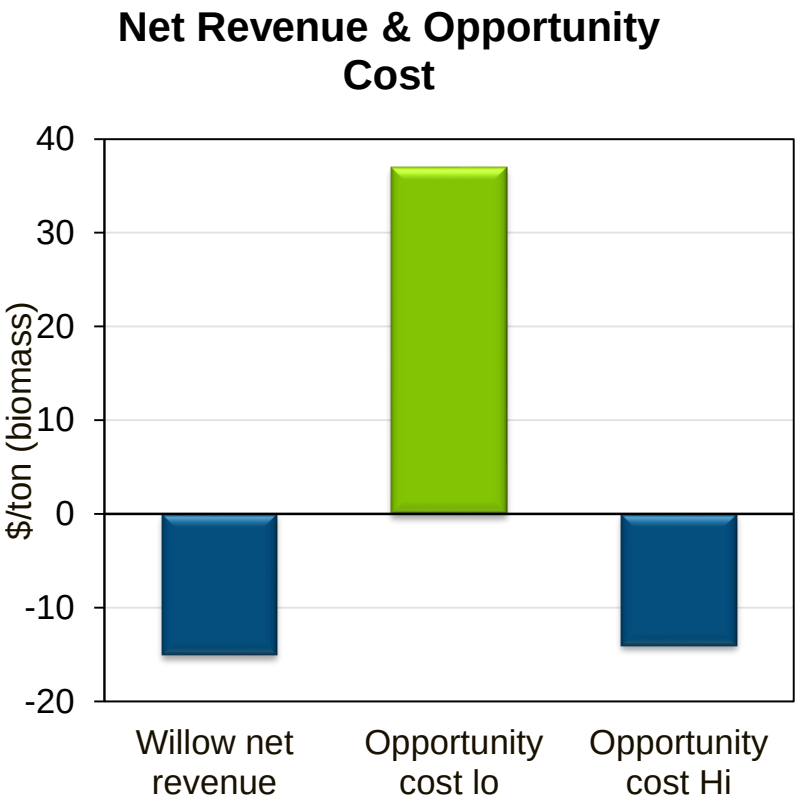
RESULTS FOR UPPER VERMILION WATERSHED



- Replacement of commodity crops in marginal land by switchgrass results in slightly decreased overall value for the commodity crops
- However, inclusion of ES valuations could change situation to a positive
- Value of reduced nitrate *alone* would create a net gain of $20 to $90 million, depending on market for nitrate reduction.

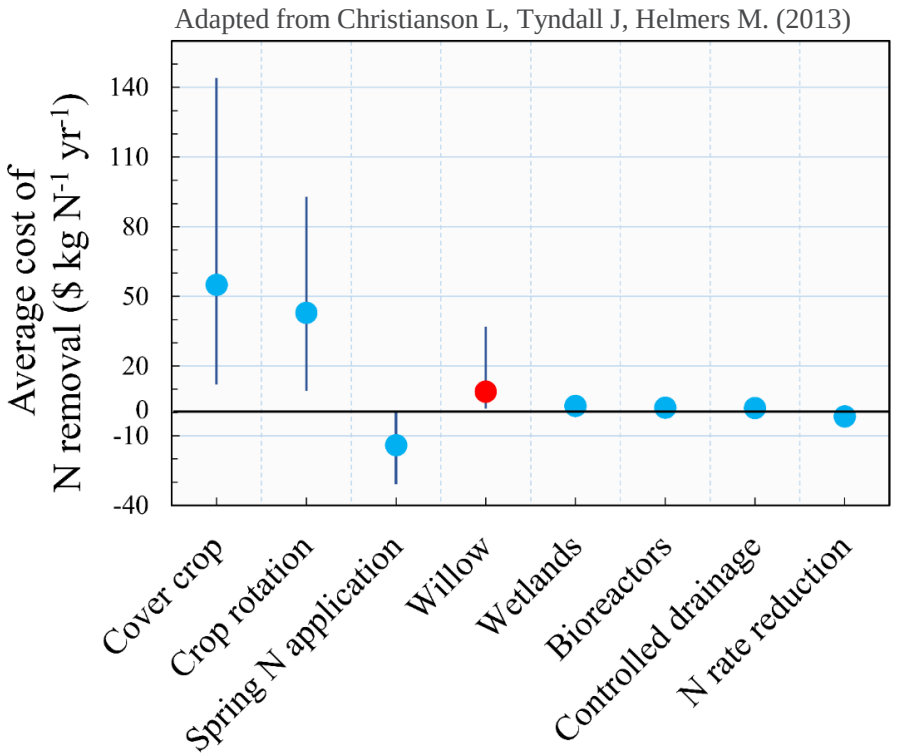
Mishra et al., (2019) https://onlinelibrary.wiley.com/doi/abs/10.1111/gcbb.12602

FIELD ECONOMICS AND COST OF N REMOVAL



Competitive in marginal land

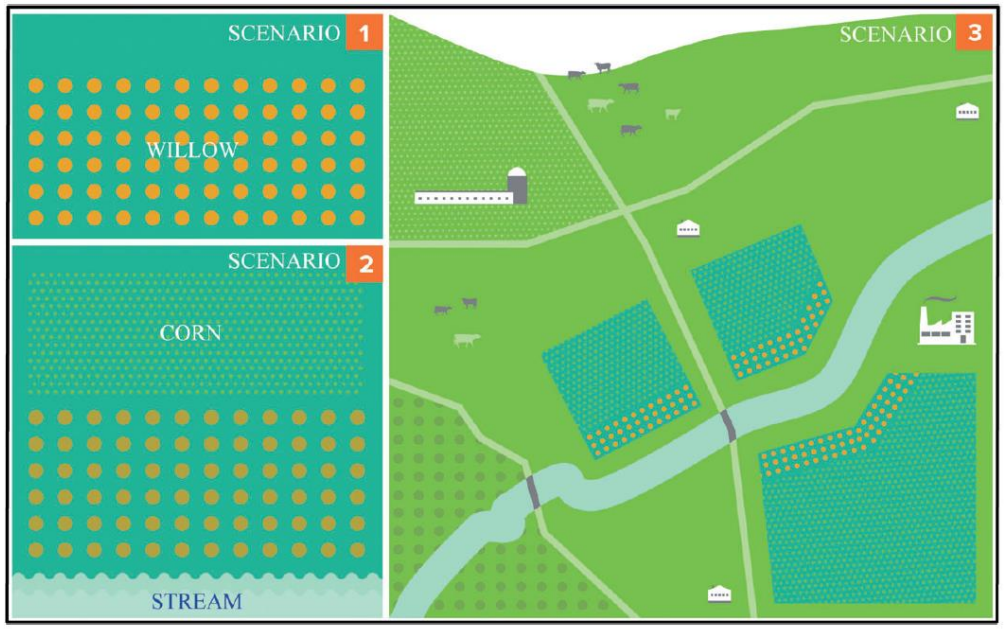
Cost competitive as a conservation option



H. Ssegane, C. Zumpf, M. C. Negri, P. Campbell, J. Heavey, and T.A. Volk (2016) -**The Economics of Growing Shrub Willow as a Bioenergy Buffer on Agricultural Fields. A case study in the Midwest Corn Belt**. Biofuels, Bioproducts and Biorefining. DOI: 10:1002/bbb.1679.

LIFECYCLE ANALYSIS (LCA)

- LCA of GHG emissions prepared for bioenergy integrated in the Indian Creek watershed
  - Willow replacing corn in marginal land
  - Energy for feedstock production, emissions from agrichemicals
  - Tested various scenarios (figure) and a range of scales
  - Based on previous economic analysis showing cost-competitiveness with other conservation practices

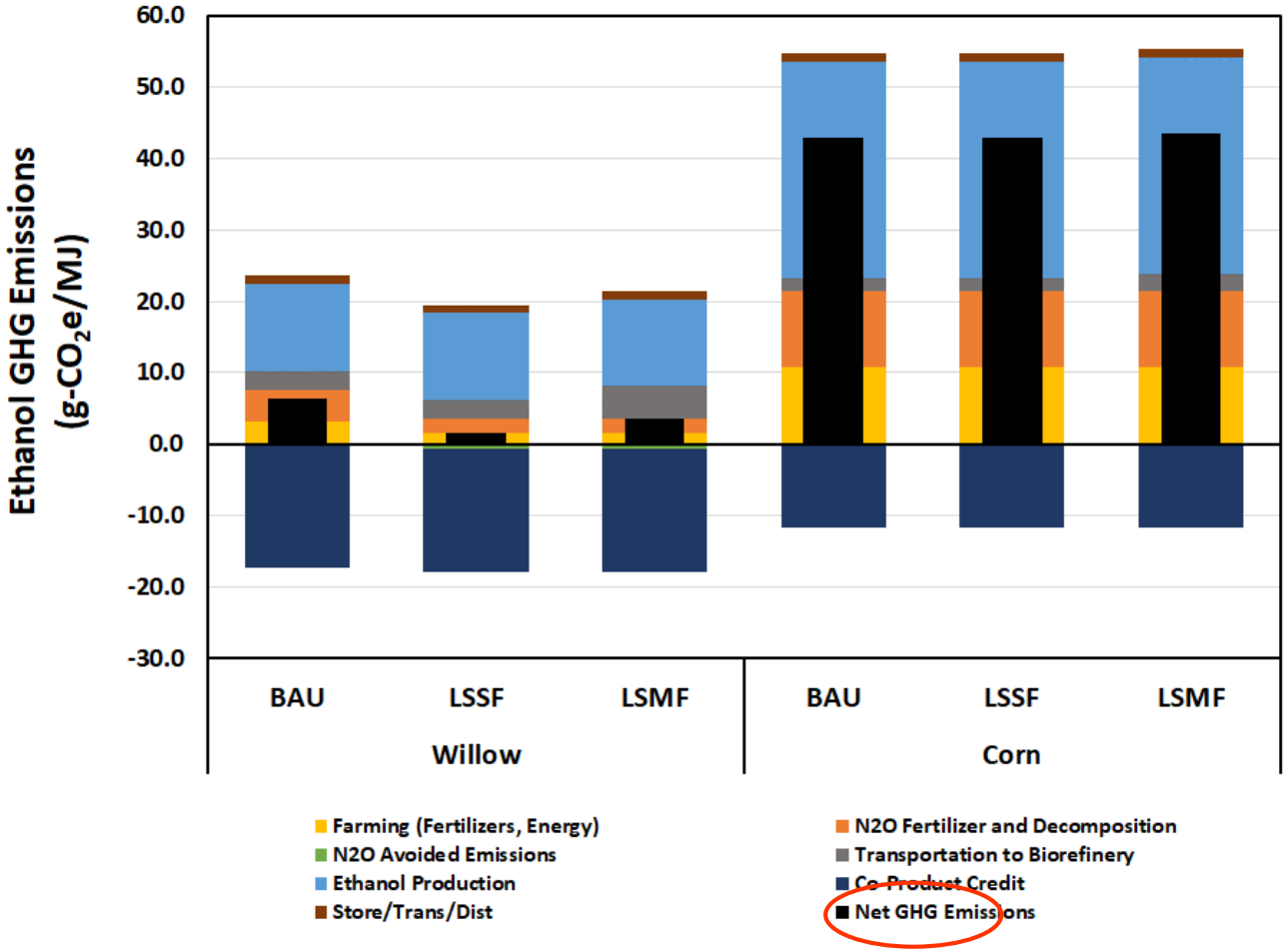


Conceptual diagrams of the three scenarios evaluated.
Scenario 1 – BAU (single field, fertilizer application, headland);
Scenario 2 – LSSF (single subfield, no fertilizer, no headland); and
Scenario 3 – LMSF (multiple subfields across the watershed). Not to scale.

LIFECYCLE ANALYSIS RESULTS

GHG emissions from producing willow on marginal land were less than half of those from producing corn on that land.

- Most benefit is due to less fertilizer, energy, agrichemicals in willow plots
- Sensitivity analysis: results most sensitive to willow yield



Manuscript in preparation

TECHNO-ECONOMIC ANALYSIS

- TEA focused on Integrated Landscape Management
  - In collaboration with INL
    - INL: field operations optimization
    - ANL: ecosystem services (ES) valuation

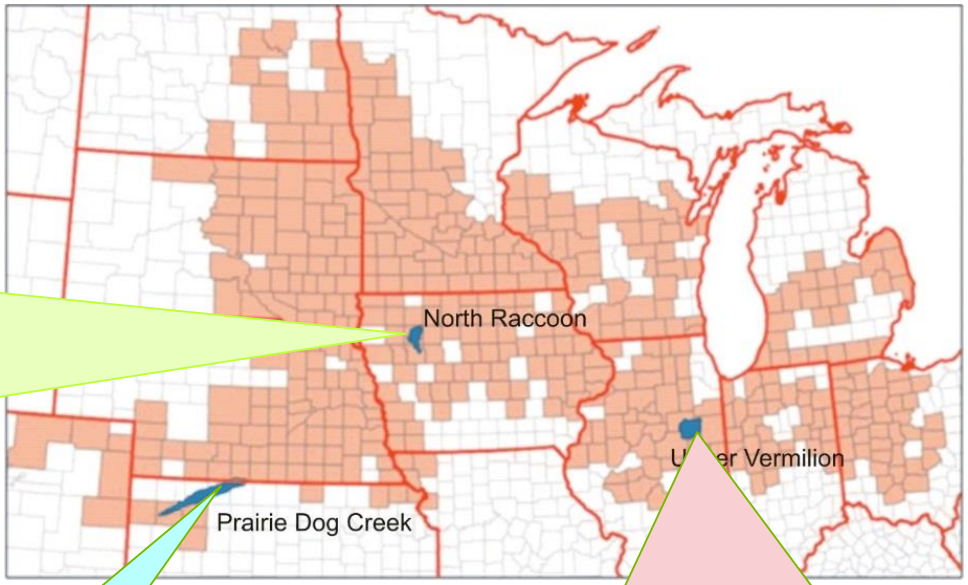
- Goal – evaluate how the valuation of ES can affect the economics of bioenergy crops
  - several test locations across the Midwest
    - Representing a range of climate, soil types, ag methods., ES markets
  - apply the methods of both National Labs

ONGOING WORK WITH INL (FY19)

449 counties identified in BT16 as generating at least 50,000 dt of corn stover

North Raccoon, IA

- Location of INL projects
- Agriculturally intense, includes tile drainage and downstream metropolitan area (Des Moines) with nitrate issues at water treatment facility
- Argonne is performing marginal land analysis and SWAT model calibration.



Prairie Dog Creek, KS/NE

- Jointly selected
- Several reservoirs with recreational aspect for ES, of interest because of its overlap with a highly stressed portion of the Ogallala Aquifer. Rain fed bioenergy crops would provide operational efficiencies (INL's analysis) and an ES service (Argonne).
- Argonne is performing marginal land analysis and SWAT model calibration.

Upper Vermilion, IL

- Location of Argonne field site
- Agriculturally intense, tributary to Illinois River
- SWAT modeling (for erosion, water quality) completed
- Potential for nutrient trading with wastewater treatment plants (WWTPs) in a major metropolitan area (Chicago).

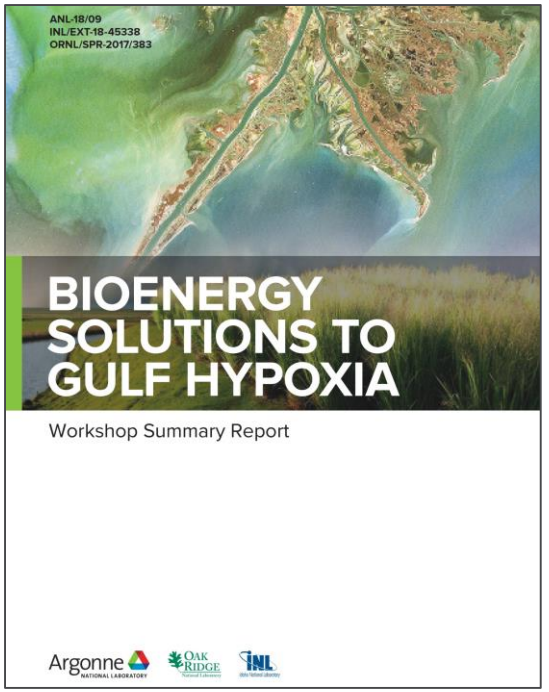
BIOENERGY CROPS AS A CONSERVATION PRACTICE?

- Goal: formulate a path for approval of bioenergy buffers as a USDA-approved soil conservation method
  - Energy crops integrated into the agricultural landscape – consistent with conservation practices
  - Supported through field research and modeling efforts that indicate significant conservation benefits.

RATIONALE

- Work with USDA to chart a path towards the adoption of bioenergy buffers by USDA-NRCS as an approved conservation practice
  - To promote bioenergy and rural economies
  - To realize water quality improvement (nutrient loss reduction, erosion reduction)
  - To realize additional ecosystem services

- Benefits for the bioenergy community:
  - Approved practice status could favor the monetization of the conservation value provided, help reduce farmer costs to conversion facilities.
  - Goes towards recognizing the total economic value of landscape-based bioenergy systems, and the attainment of the <$3/gge goal.
  - Overall contributes to the sustainability branding of lignocellulosic biomass.



PATH FORWARD

- Concept discussed favorably with USDA-NRCS staff
- Need to define jointly the research path to complete the needed scientific rationale for approval
  - Assembling a team effort with other researchers from universities, ARS, NRCS, others
  - Convene team and identify research gaps
- Two possibilities for approval of bioenergy buffers discussed:
  - New, separate conservation practice
  - Combine with an existing conservation practice

Continuing strong outreach program

- Vermilion Headwaters Watershed Partnership Advisory Committee
- Illinois Nutrient Loss Reduction Strategies working group

FRAMEWORK INTEGRATION

- Goal: to create a geospatial model that can access databases and output environmental and economic indicators. This integrated model will allow for faster scale-up of scenario analysis.
  - water quality, pollinator habitat, biodiversity, farmer economics and lifecycle emissions
  - In progress with Argonne programmer/GIS staff team (FY19)

4 – RELEVANCE

- 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, provides example and data for models, how do ideas turn to practice?
    - Contributes to fulfilling BETO goal of validating landscape design approaches.
- To the conversion industry: identifies ways to intensify biomass supply, offer alternative business model, and prepares community for investments in bioenergy.

Barriers addressed

Strategic Analysis and Crosscutting Sustainability

At-E. Quantification of Economic, Environmental, and Other Benefits and Costs

At-F. Science-Based Methods for Improving Sustainability

At-H. Consensus, Data, and Proactive Strategies for Improving Land-Use Management

4 – RELEVANCE – CONT'D

Relevance to broader community:

- Rural communities: Provides producers with a value proposition. Considers needs and barriers within farming community and gives stakeholders 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.
- State: provides best practices and an avenue to cost-effectively meet Nutrient Loss Reduction Strategies requested by Hypoxia Task Force.
- Society: provides concepts and data to develop alternative land management systems to deliver food, feed, energy and ecosystem services.
- Scientific community: provides primary data for models, methods and procedures for collaborative research and meta-analyses.

5 – FUTURE WORK

- **Complete last year of field monitoring and harvest second coppice in Winter 2019**
  - Continue biodiversity monitoring protocol
  - Understand yield changes and water quality through second cycle
  - Demobilize and close site
- **Complete design** analysis of saturated bioenergy buffers for improved production and nutrient removal at drainage structures.
- **Continue to develop TEA with INL**
  - Understand potential markets for ES
  - Complete evaluation of ES value, develop a calculator tool for ES
- **Formulate the case** for bioenergy landscapes in conservation practice
- **Assemble all elements into a streamlined framework** for planning and analysis at larger scale, develop network of observatories.
- ***Scale up*** *to larger scale (County, State) in future project cycles*.

SUMMARY

1. Field study, small watershed, and larger scale modeling show potential for the accrual of significant ecosystem services to accompany biomass production in agricultural landscapes
2. GHG emissions, water quality benefits, and economics are favorable to placement of willow strips in marginal land
3. **Surpassed performance goals for improved water quality**
4. Strong outreach efforts helping to shape the opportunity
5. **This project is helping BETO find a novel economic and environmental paradigm to improve the penetration of bioenergy crops into working agricultural lands, proposing a benign intensification of land use that improves our natural capital**
6. Project is completing funding cycle. Future work will seek to scale up the analysis.

ADDITIONAL SLIDES

RESPONSES TO PREVIOUS REVIEWERS' COMMENTS

- "the team plans to… develop pathways to include bioenergy landscapes in conservation BMPs"
  - We have discussed with NRCS our project and its primary data from the field regarding whether it could be adopted as a new conservation BMP or included with an existing BMP.
- "It would be helpful for the project team to demonstrate stronger connections to the other techno-economic and environmental analyses occurring in BETO."
  - During the review period (and continuing), we have been working with colleagues at INL on a TEA focused on integrated landscape management. INL produces the field operation optimization results, while ANL focuses on the valuation of ecosystem services. Analyses are focused on study areas in NE, KS, IA, and IL and represent a range of environmental settings.

PUBLICATIONS COMPLETED SINCE 2017 OR IN PROGRESS

1.Mishra, S.K., M.C. Negri, J. Kozak, J. Cacho, J. Quinn, S. Secchi, and H. Ssegane, *in press*, Valuation of Ecosystem Services in Alternative Bioenergy Landscape Scenarios: Global Change Biology Bioenergy.

2.Canter, C.E., K. Zolton, J.F. Cacho, M.C. Negri, C.R. Zumpf, and J.J. Quinn, *in prep*., Life-cycle analysis of shrub willow production as bioenergy buffers in a U.S. Midwest corn production system.

3.Dimitriou, I., G. Berndes, O. Englund, M. Brown, G. Busch, V. Dale, G. Devlin, B. English, K. Goss, S. Jackson, K.L. Kline, K. McDonnell, J. McGrath, B. Mola-Yudego, F. Murphy, M.C. Negri, E.S. Parish, H. Ssegane, and D. Tyler, 2018, Lignocellulosic Crops in Agricultural Landscapes: Production systems for biomass and other environmental benefits – examples, incentives, and barriers: IEA Bioenergy Task 43, 28 pp. http://task43.ieabioenergy.com/publications/lignocellulosic-crops-in-agricultural-landscapes/

4.Zalesny, R.S., G. Berndes, I. Dimitriou, U. Fritsche, C. Miller, M. Eisenbies, S. Ghezehei, D. Hazel, W.L. Headlee, B. Mola-Yudego, M.C. Negri, E.G. Nichols, J. Quinn, S.D. Shifflett, O. Therasme, T.A. Volk, and C.R. Zumpf, *in press*, Positive water linkages of producing short rotation poplars and willows for bioenergy and phytotechnologies: WIREs Energy and Environment.

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Presentations since 2017:

1. Negri, C., S. Mishra, J. Cacho, and J. Quinn, 2018, Valuation of Benefits from an Alternative Bioenergy Landscape: Biennial meeting of A Community on Ecosystem Services, Dec. 3-7, 2018, Washington D.C. (invited)
2. Zumpf, C., J. Cacho, J. Quinn, P. Campbell, M.C. Negri, and D.K. Lee, 2018, Impact of Shrub Willow Buffers in an Agricultural Landscape: Illinois Nutrient Loss Reduction Strategy (NLRS) Second Annual Workshop, University of Illinois, November 13.
3. Negri, C., J. Quinn, J. Cacho, C. Zumpf, S.K. Mishra, and P. Campbell, 2018, Ecosystem Services: towards the understanding of the total economic value of bioenergy landscapes: DOE Bioeconomy 2018, San Francisco, November 7-9.
4. Zumpf, C., C. Negri, D.K. Lee, J. Quinn, P. Campbell, and J. Cacho, 2018, Assessment of the Ecosystem Service Potential of a Shrub Willow Buffer in a Corn-Soybean Field, 2018 International Annual Meeting of the American Society of Agronomy, the Crop Science Society of America, and the Canadian Society of Agronomy, Baltimore, MD, November 4-7.
5. Quinn, J.J., M.C. Negri, C. Zumpf, J. Cacho, P. Campbell, S.K. Mishra, H. Ssegane, 2018, Integrated Landscape Management for Improving Water Quality in the Midwest: Geological Society of America, Annual Meeting, Indianapolis, November 4-7, Abstracts with Programs. Vol. 50, No. 6, ISSN 0016-7592 doi: 10.1130/abs/2018AM-321884
6. Mishra, S.K., M.C. Negri, J. Cacho, and J. Quinn, 2018, Valuation of Ecosystem Services in Alternative Bioenergy Landscape Scenarios: Agricultural and Applied Economics Association (AAEA), Annual Meeting, Washington, D.C., August 5-7.
7. Cacho, J. F., Negri, M. C., Zumpf, C. R., Campbell, P., Quinn, J. J., Ssegane, H.,2018, Environmental benefits of shrub willow as bioenergy strips in an intensively managed agricultural system: 2018 International Short Rotation Woody Crops Conference, July 23-25, Nicolet College, Rhinelander, WI.
8. Zumpf, C., D.K. Lee, M.C. Negri, J. Cacho, P. Campbell, and J. Quinn, 2018, Food, Energy & Environment: Impact of Shrub Willow Buffers in an Agricultural Landscape: Fourth Annual International Food Security Symposium, University of Illinois, April 30-May 1.
9. Quinn, J.J., M.C. Negri, C. Zumpf, P. Campbell, J. Cacho, H. Ssegane, 2018, Multifunctional Landscapes and Water Quality in the Midwest: Geological Society of America, North-Central Section Meeting, Ames, Iowa, April 16-17, Abstracts with Programs. Vol. 50, No. 4, doi: 10.1130/abs/2018NC-312404
10. Zumpf, C., M.C. Negri, D.K. Lee, J. Cacho, P. Campbell, and J. Quinn, 2018, Ecosystem Service Provision by Shrub Willows in an Illinois Agricultural Landscape: International Association for Landscape Ecology IALE 2018 Annual Meeting, April 8-12, Chicago.

9. Mishra, S.K., 2018, Ecosystem Services Valuation Methods and Tools, Natural Capital Symposium, March 19–22, Stanford University.

10. Negri, M.C., J. Cacho, C. Zumpf, P. Campbell, H. Ssegane, and J. Quinn, 2017, Nitrogen Recovery and Biomass Production: Environmental and Economic Benefits: Illinois Nutrient Loss Reduction Strategy (NLRS) Inaugural Partnership Conference, Springfield, IL, November 28-30.

11. Cacho, J., 2017, Integrating perennial bioenergy crops into agricultural landscapes for biomass and soil and water quality benefits, ASA-CSSA-SSSA International Conference, October 22–25, Tampa, FL.

12. Zumpf, C., M.C. Negri, D.K. Lee, J. Cacho, and P. Campbell, 2017, Soil Quality and Biodiversity Impacts of Shrub Willow on an Agricultural Landscape, ASA-CSSA-SSSA International Conference, October 22–25, 2017, Tampa, FL.

13. Negri, M.C., 2017, Maximizing bioenergy resources in the Midwest, Midwest Governors Association meeting, October 11–12, Iowa City, IA (invited).

14. Cacho, J., 2017, The viability of shrub willow as bioenergy buffer on intensively managed agricultural fields of U.S. Midwest: Soil and Water Conservation Society International Conference, Madison, WI, July 30 to August 2.

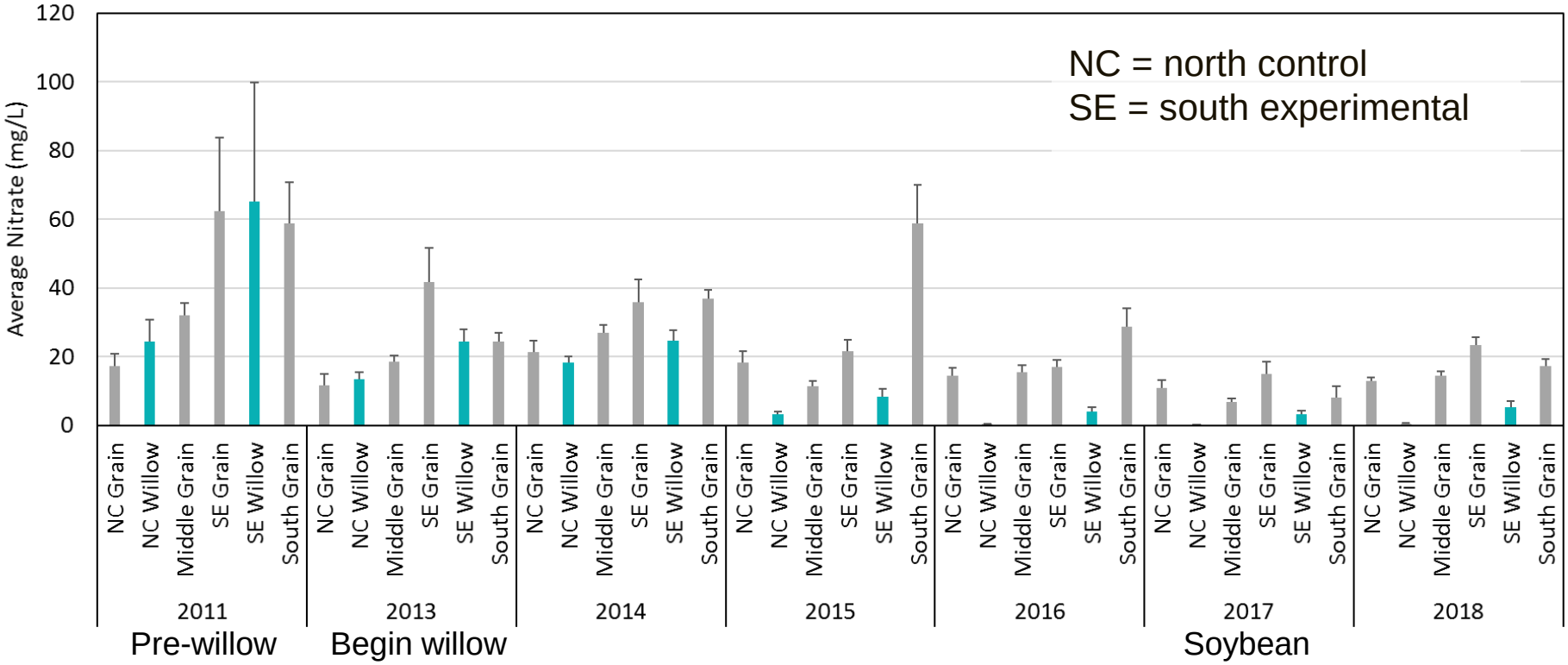
15. Negri, C., 2017, Food and Science, Argonne Outloud Lecture, Argonne National Laboratory, July 20.

18. Negri, C., 2017, Environmental Entrepreneurship Opportunities in the Bioeconomy. Interactive poster presentation at Bioeconomy 2017, Arlington, VA, July 12-13.

19. Negri, C., 2017, A nutrient reuse approach for improved biomass yields, water quality and economics: European Biomass Conference, Stockholm, Sweden, June 12-15 (invited).

20. Negri, C., H. Ssegane, S. Secchi, J. Kozak, J. Cacho, and P. Campbell, 2017, Valuation of Environmental Ecosystem Services and Benefits of Bioenergy Crop Integration into Agricultural Landscapes: International Association for Landscape Ecology IALE-2017 Conference, Baltimore, MD, April 9-12.

RESULTS: NO_3-N LEACHATE ANALYSIS



Zumpf et al. (2017) plus newer data

Nitrate leaching between the willow and grain were significantly different in 2015-2018.

The Goal to reduce leached nitrate by 30% compared to BAU was met in 2015.

IMPROVEMENTS TO PROCESS EFFICIENCY: SATURATED BIOENERGY BUFFER (SBB) ANALYSIS

- Reviewed and summarized the suitability criteria for sites as SBBs (e.g. soil drainage, topography, conditions for denitrification, streambank erosion)
- Developed algorithms to implement SBB suitability criteria, conducted using GIS-based Multi-Criteria Decision Analysis (MCDA) technique in ArcGIS Desktop 10.3.1.
- Validated the method, which identified 5 suitable sites out of the 7 saturated buffer sites in the Midwest that were deemed by Utt et al. (2015) as effective in reducing drainage nitrate loading
- Hydrologic and water quality calibration of sites using DRAINMOD
- DeNitrification-DeComposition (DNDC) model for the sites to estimate productivity & environmental benefits
- Manuscript in prep