Enabling Sustainable Landscape Design for Continual Improvement of Operating Bioenergy Supply Systems

(Award No: EE0007088)

U.S. Department of Energy (DOE)
Bioenergy Technologies Office (BETO)
2021 Project Peer Review,
March 10, 2021

Data, Modeling, & Analysis Session

Kevin Comer, Principal
kcomer@antaresgroupinc.com
Office: (540) 227-8866

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Quad Chart Overview

Timeline

- Project start date: April 1, 2016
- Project end date: Sept. 30, 2021

Source of Funds	FY 20 Costed	Total Award
DOE Funding	$0.94M	$9.00M
Project Cost Share	$0.73M	$1.50M

Partners (Budget Amounts): Iowa Dept. of Ag. & Land Stewardship (21%), USDA ARS (17%), Antares (15%), FDC Enterprises (13%), INL (10%), Penn State (7%), AgSolver/EFC Systems (3%), ORNL (4%), ANL (2%), All Others (8%)

Project Goal

This project will develop and demonstrate new tools and approaches for planning and implementing *sustainable landscape design strategies aimed at simultaneously improving farm profitability, environmental sustainability, and future sustainable biomass supply production*, thereby improving the viability of future herbaceous biomass supply systems and projects.

End of Project Milestones

- Case study examples for various demonstrated strategies
- Field monitoring results and data, multiple years
- Applied analytical tool improvements
- Landscape Design “Handbook”
- Increased state and local experience with these strategies

Funding Mechanism

FOA Number DE-FOA-0001179:
Landscape Design for Sustainable Bioenergy Systems

1 - Project Overview

Required Areas of Focus:

1. Multi-Stakeholder Landscape Design Process
2. Assessment of Environmental Sustainability Indicators
3. Assessment of Feedstock Supply and Logistics
4. Help to build a template for future biorefinery projects

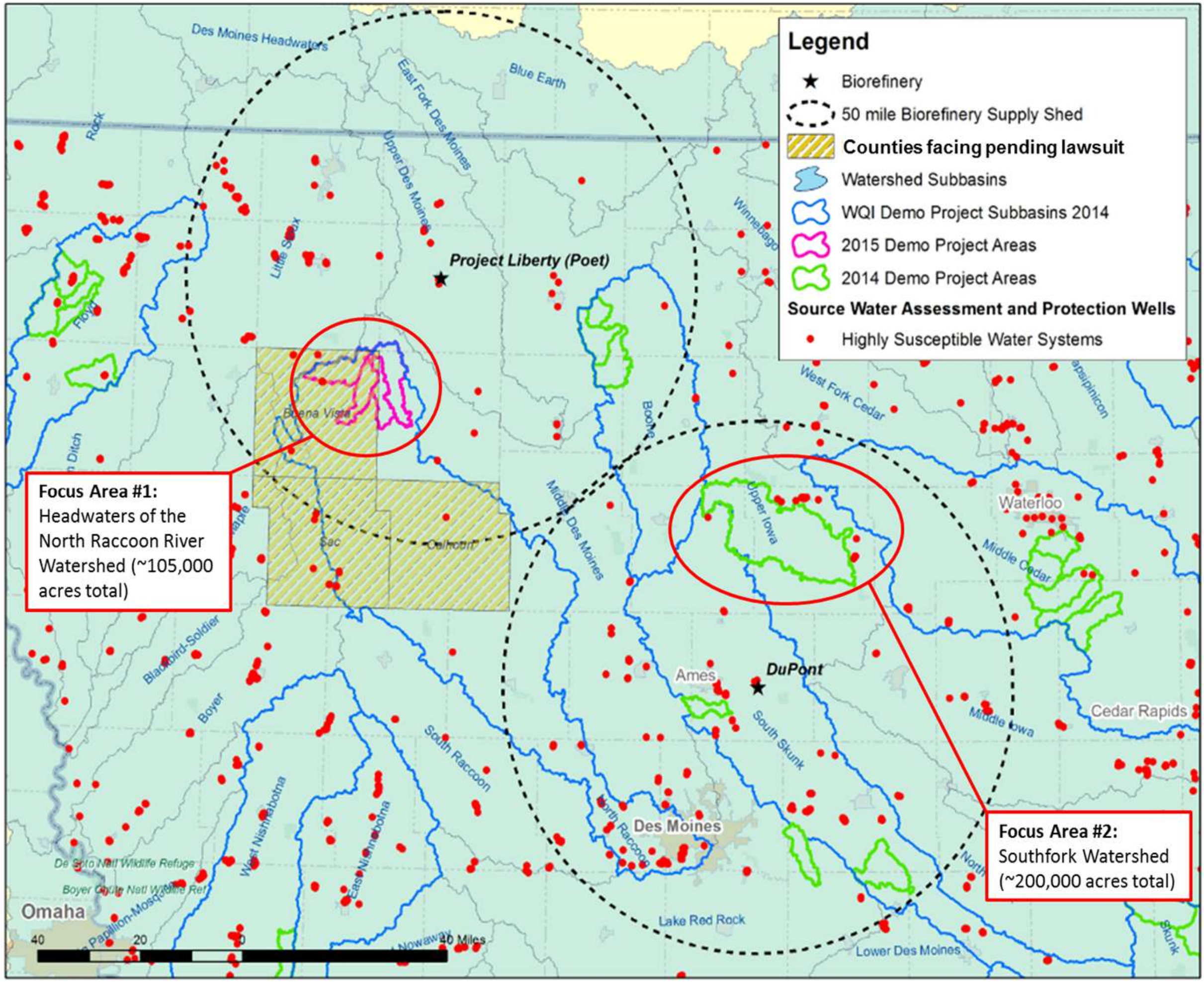
Primary Funding:

Project Team:

Collaborators:

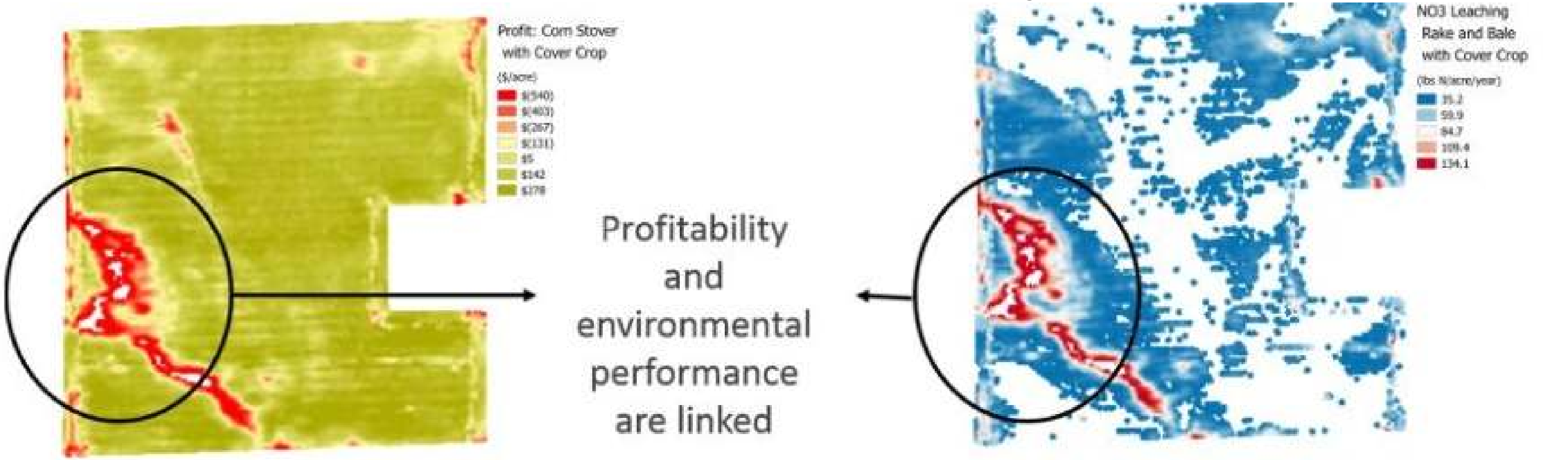
1- Project Overview: Targeted Watershed Areas

- DOE FOA required focus on one watershed of at least 10,000 acres
- Two biorefineries in start-up mode
- Iowa Nutrient Reduction Strategy Goals
  - Non-point
  - 41% less N
  - 29% less P
- Hundreds of millions spent annual towards nutrient reduction goals
- Better decision-making tools needed for planning at all scales

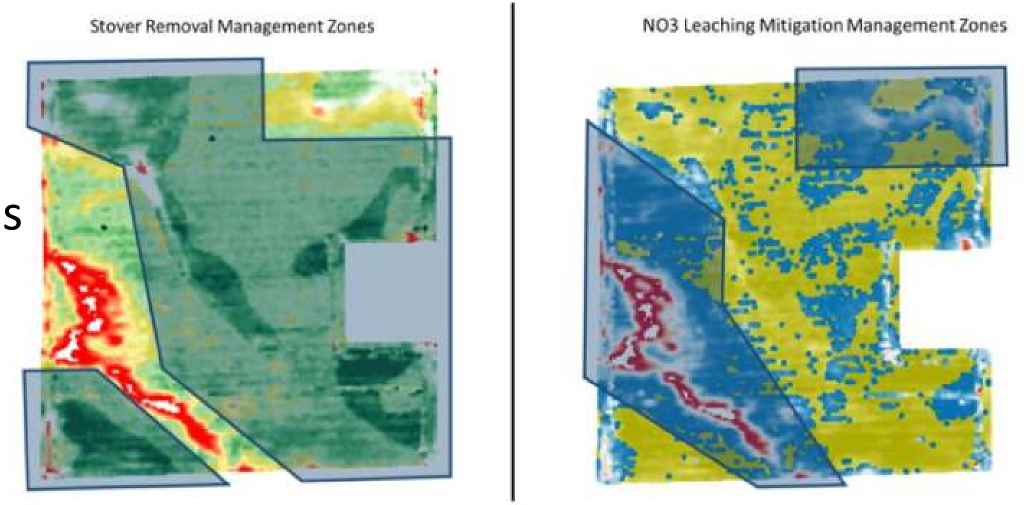


1 - Project Overview (Subfield Analytics)

- **Goal:** Demonstrate use of advanced analytics and computing capabilities to facilitate improved decision-making in agriculture



- **Previously:** Based on field-level profit analysis, experience, intuition & field observations—lost revenue & environmental benefits potential
- **Importance:** Can inform management decisions to improve profitability, environmental performance, and biomass supplies
- **Risks:** Lower biomass yields on marginal acres; Ground-truthing of env. models needed



1 - Management

Overall project management and oversight provided by Antares Group, with project tasks assigned to "subgroups" of experts.

Monthly technical & management meetings, annual meetings, *constant coordination*.

Project Tasks:

1. Multi-stakeholder Landscape Design Process

   Led by Antares Group, contributions by AgSolver & FDC Enterprises, Full Team
2. Assessment of Environmental Sustainability Indicators

   Led by ORNL, contributions by USDA-ARS, AgSolver, Penn State, & Antares
3. Assessment of Feedstock Supply and Logistics

   Led by INL, contributions by ORNL, Penn State, Antares Group, FDCE, ISU
4. Analytical Approaches for Subfield Analyses

   Led by AgSolver, contributions by Penn State, INL, Purdue, ANL
5. Targeted Feedstock and Environmental Assessment Data

   Led by USDA-ARS with contributions by Antares & FDC Enterprises

Review Criteria:

- Critical milestones tracked via DOE project management systems
- Problems identified promptly and solved via team collaboration
  - Scheduled team meetings (124+)
  - Estimated local stakeholder meetings (~150)
  - Ad hoc as needed
- Related projects welcomed and encouraged by team/DOE

2 – Approach: Biomass Supplies

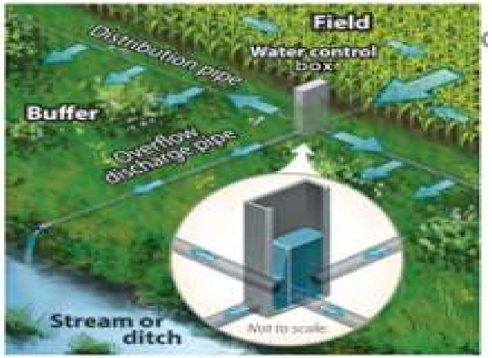
Four primary biomass supply-related strategies:

Sustainable Stover Removal, without Cover Crops

Sustainable Stover Removal, with Cover Crops

New/Increased Biomass Supply Potential

Perennial Grasses on Marginal Lands

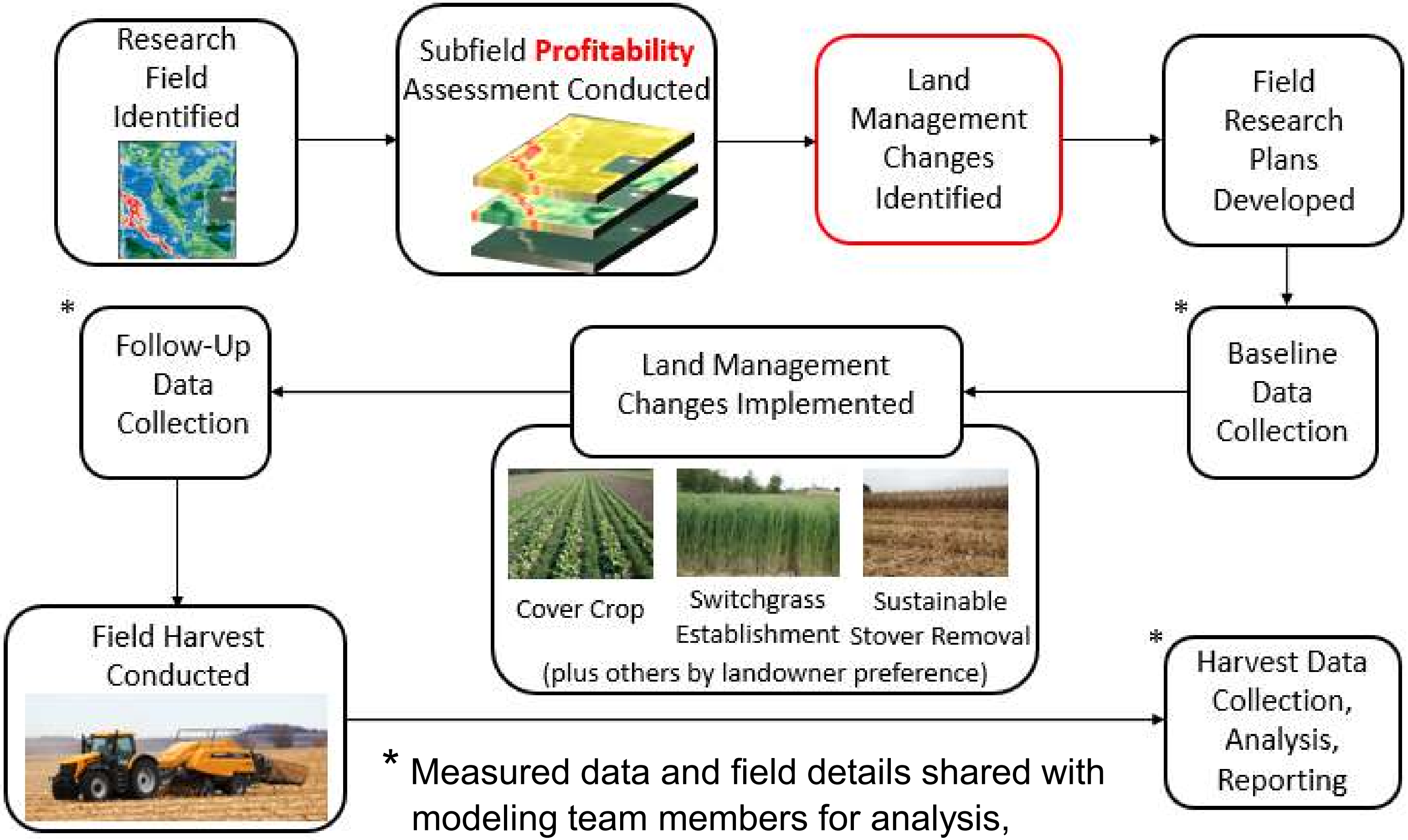


Source: Frankenburger et al., unpublished

Saturated Buffers with Perennial Grasses

- USDA research plots & collaborator fields leveraged for annual corn stover harvest demos and data collection
- Recruited ~3,000 acres of marginal farmland for establishment to perennial grass mix
  - Goal was 1,700 acres
  - USDA ARS field sampling and reporting in perennial grass and Business-As-Usual Fields
  - Soil health reports to landowners for sampled acres
- Switchgrass harvests annually on up to ~2,000 acres in Virginia

2 – Approach (Simplified)



* Measured data and field details shared with modeling team members for analysis, reports, and publications.

- **Top Challenges:**
  - Uncertainties associated with cellulosic biofuel industry (managed)
  - Field recruitment timelines and needed process (solved, valuable lessons learned)
  - Data volumes for state-wide subfield modeling results (in progress)
- **Metrics & Go/No-Go:**
  - Acreage goals, exceeded by ~1,300 acres planted
  - Sampled fields (24 goal vs. 38 fields sampled)
  - Subfield modeling goals (greatly exceeded)
  - Stage Gate review, milestone progress

3 – Impacts: Straeter Cornrower Header Operation

- Enables higher sustainable stover removal rate (compared with conservative harvest), esp. w/ cover crop
- Low added O&M: <$1/ton
- Low Ash: ~5.5%
- In-field pre-processing possible
- Single-pass harvest to be developed






- INL published paper on cost analysis
  - Cost impacts between reduction of ~$14/ton to increase of ~$1-2/ton depending on crop conditions & yields
- ISU (Stu Birrell) has developed and tested variable rate controls for real-time sustainable stover removal
- Header & controls tested and improved annually throughout project

3 – Impacts (Field-level Example)

Scenario: Actual Production

Parameter	Value
Field Acreage	143.3 ac
Average Yield	170.2 bu/ac
Profit	$49.63/acre
ROI	6.2 %
Production Efficiency	212.4 bu/$1000
Acreage Opportunity Ratio	23 %
Working Capital Opportunity	$25,973.83
Total Field Expenses	$114,800.50
Total Field Revenue	$121,912.06
Total Field Profit	$7,111.56

Scenario: Conservation-Final

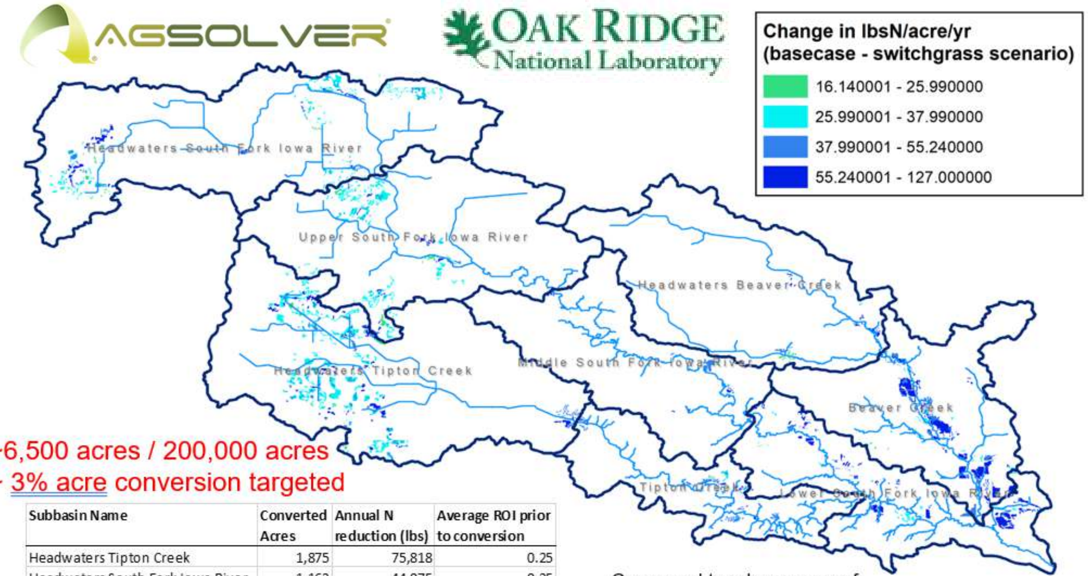
Parameter	Value
Field Acreage	143.3 ac
Average Yield	179.2 bu/ac
Profit	$93.85/acre
ROI	12.6 %
Production Efficiency	239.7 bu/$1000
Acreage Opportunity Ratio	22 %
Working Capital Opportunity	$19,494.23
Total Field Expenses	$107,085.95
Total Field Revenue	$120,534.99
Total Field Profit	$13,449.04

- 143 acre field
- 5-yr production history showed >$500/yr profit losses in 15 acre sandy ridge area (red area on left)
- After conversion of that area to conservation program
  - Per acre profit and return on investment roughly double
  - Overall profit increased by >$6,000
- Bioenergy Supply Impacts:
  - 15-acre area could be planted to perennial bioenergy crop
    - 30 to 45 tons potential biomass yield
    - Incentives likely needed
  - Variable rate stover removal could add estimated 80 to 100 tons per year (sustainably), depending on yields

3 – Impacts (Watershed / Supply Shed / State Example)

- AgSolver Profit Zone Manager™ analysis indicates 5 to 20% of production fields are consistently not profitable.

Analysis of Iowa's South Fork Watershed:
Potential reductions in nitrate leaching following switchgrass plantings on clustered areas of low ROI



~6,500 acres / 200,000 acres
~ 3% acre conversion targeted

Subbasin Name	Converted Acres	Annual N reduction (lbs)	Average ROI prior to conversion
Headwaters Tipton Creek	1,875	75,818	0.25
Headwaters South Fork Iowa River	1,163	44,075	0.25
Beaver Creek	1,107	72,057	0.21
Upper South Fork Iowa River	1,006	38,871	0.26
Lower South Fork Iowa River	789	50,546	0.18
Tipton Creek	298	15,804	0.21
Middle South Fork Iowa River	140	6,557	0.26
Headwaters Beaver Creek	100	5,232	0.15
South Fork Total	6,477	308,961	

Compared to a base case of conventional till corn/soy with no cover crop, no residue removal, and fall fertilizer application

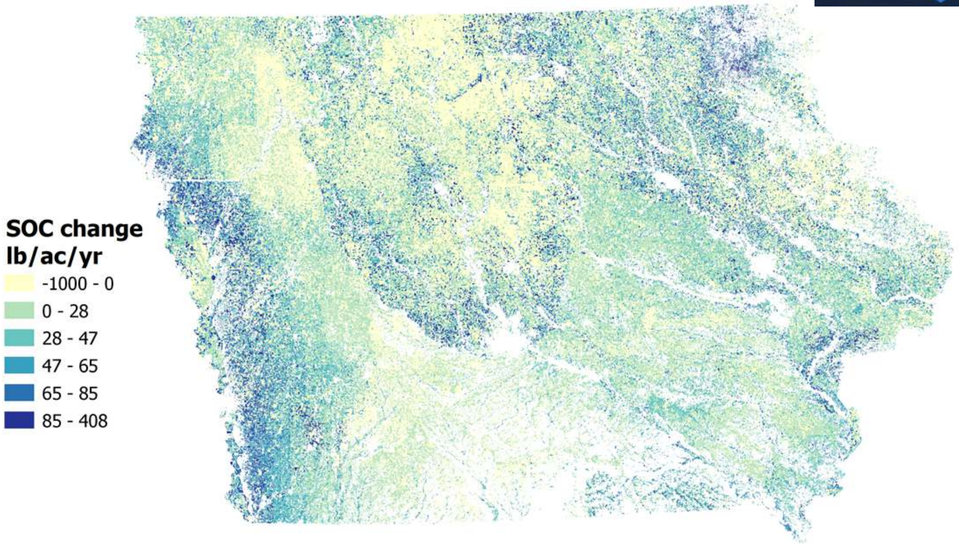
Analysis of AgSolver datasets by Esther Parish of ORNL, 2 July 2019

- Identified clusters of low Return On Investment, high nitrate leaching acres
- Clustering based on harvest densities employed by FDCE in Virginia switchgrass harvests
- 6,500 acres identified for switchgrass bioenergy plantings, ~3% of total 200,000 acre watershed
- Applied to a 50-mile radius supply shed, at 3 ton/acre, ~500,000 ton/yr supply
- Applied state-wide, 26.0 million acres cropland, ~2.3 million ton/yr supply (~10 commercial-scale biorefineries)

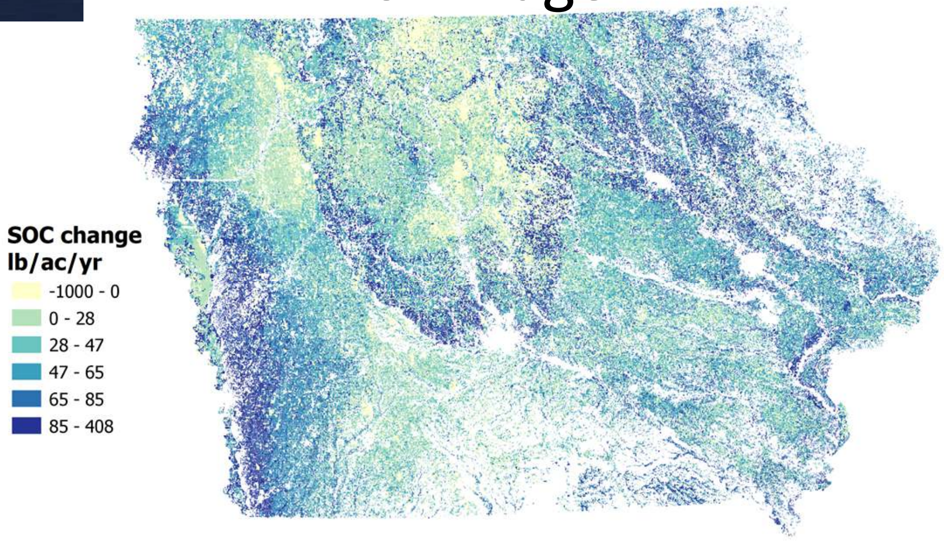
3 – Impacts (State-level Soil Carbon Example)

Average Simulated SOC Change from Business as Usual (BAU) with 30% stover harvest and a rye cover crop

- Reduced Tillage



- No-Tillage



Increased dark blue color illustrates greater SOC accumulation with No Tillage than Reduced Tillage practices throughout Iowa, USA.

4 – Progress and Outcomes, Summary

- Recruited and established ~3,000 acres of perennial grass on marginal lands
- USDA ARS developed research plan and sampled 38 fields, 3 research farms
  - Landowner soil health reports in preparation
- AgSolver commercialized its Profit Zone Manager™ software, now incorporated into EFC Systems' FieldAlytics™ software platform
- ISU developed and demonstrated variable rate sustainable corn stover harvest controls and software for New Holland Cornrower
- 30 published papers and reports: soil health, agronomic issues, nutrient management impacts, harvest logistics, stakeholder preferences/feedback, greenhouse gas impacts, wildlife diversity impacts, decision support tools, etc.
- Extensive state-wide subfield agronomic & environmental analyses completed
  - 96 unique cases, ~1.2 trillion calculations, currently developing Tableau interface for visualization
  - Various combinations of tillage practices, fertilization application, residue removal rates, cover crop use
  - Far exceeds FOA requirements
- Project Handbook well under way (18 case studies, initial goal was 5), due Sept. '21
- *Broadly qualified, cooperative team critical to solving challenges and making progress*

END OF PRESENTATION: ADDITIONAL SLIDES

Responses to Previous Reviewers' Comments

- **Significant Questions/Criticisms from Previous Peer Review Report:**
  - Reviewer Comment: This is, even when pursued on a relatively small scale, a very expensive undertaking (something on the order of $12 million), though one of the strengths of the approach is leveraging contributions from other sources.
  - Response: Our team recognizes the importance of and magnitude of this amount of funding, and the importance of putting those funds to productive and meaningful use with practical, actionable outcomes. We also recognize that this project is very important to the Analysis and Sustainability efforts of BETO. As such, our team is seeking every available opportunity to further leverage this funding with supplemental federal, state, and private funding to enable our team to extend the reach, implementation, and applicability of our efforts. We are also continuing to reach out to other researchers and interested organizations to maximize the collaboration from our project, both to help their efforts where possible by involving them in our project and to allow our team to benefit from their efforts. These collaboration and team building efforts have been extremely successful to date.

    While $12 million is a large amount of funding, it is also helpful to put that into context with a few other important metrics: 1) the two biorefineries we were collaborating with (POET and DuPont) at the outset of this project were targeting to procure a total of about 650,000 tons of biomass per year, resulting in annual biomass procurement costs of about $52 million (@$80/ton), or about $260 million over a 5-year period that's equivalent in duration to this project's duration (hundreds of refineries of this size would be needed to reach the future targets of the Renewable Fuel Standard); 2) the BETO program and ORNL have published the "2016 BILLION-TON REPORT--Advancing Domestic Resources for a Thriving Bioeconomy", which projects hundreds of millions of tons per year of supplies needed in the future from agricultural residues and herbaceous energy crops in order to approach or achieve the vision described in that study (500 million tons/yr x $80/ton = $40 billion/yr in biomass supply value from the types of resources we are focusing on in this project), and 3) in Table 2.6 of the 2016 BILLION-TON REPORT, based on USDA census data there were less than 3,000 acres of energy crops harvested in 2012 producing less than 12,000 dry tons of biomass. This project has contracted more than that amount of acreage to be established as part of our research and demonstration efforts. In the context of the above considerations, the funding dedicated to this project is modest and necessary. It is incumbent on our team to utilize this project as an agent of change, to: 1) demonstrate opportunities for landowners and farmers to add bioenergy crops into their management practices in ways that are economically preferable and beneficial to their operations, 2) develop new and improved management and decision-making tools to facilitate better targeting of marginal farmland for energy crop production and improved environmental performance, 3) identify policy issues and options for . . . .

Responses to Previous Reviewers' Comments

- **Significant Questions/Criticisms from Previous Peer Review Report:**
  - (continued from previous page) . . . . facilitating improved value from conservation and energy crop incentive programs to enable greater future sustainable biomass supply production; 4) develop high-quality, publishable scientific field monitoring results and reports to document the merits of the management approaches and alternatives pursued in this project; 5) demonstrate, monitor, and report on equipment-related advances and issues associated with the agricultural residue and perennial herbaceous energy crop establishment and harvesting activities and strategies pursued in this project; and 6) create a template that can be deployed in other areas of the county (at much lower costs than this first project) to help implement these landscape design and management approaches to help support a growing bioeconomy while improving environmental services in project areas. Several members of our team are already engaged in efforts to deploy similar tools and techniques for planning and implementation efforts in the Chesapeake Bay Watershed area.
  - Reviewer Comment: It will be important to understand farmers' own choices that reveal information about what works in practice. Understanding and accounting for this will be critical to ensuring the tools developed will be as practical as possible.
  - Response: As part of our contracts with participating landowners, they have agreed to interact with our team to provide feedback on their choices, preferences, reasoning, criticisms or skepticism, and experiences with our team and the management practices they have made in collaboration with our project. We have powerful feedback solicitation tools and expertise (ThinkTank) involved with this project through Idaho National Lab and the USDA Agricultural Research Service, and we plan to deploy those tools to solicit feedback from key stakeholders as part of the project's activities. We will likely deploy a combination of those tools and face-to-face, one-on-one interactions to solicit this type of feedback throughout the project period. We have performed a round of face-to-face interviews with over 30 landowners who have participated in project-related activities to date, with the purpose of understanding their priorities for decision-making with respect to this project's objectives. Results of those interviews have been published by team members Idaho National Laboratory and Penn State University.

Responses to Previous Reviewers' Comments

- **Significant Questions/Criticisms from Previous Peer Review Report:**
  - Reviewer Comment: It will be critical to understand what the minimum size a subfield needs to be so that a change in management practice is practical as well as profitable.
  - Response: This is part of our team's approach and scope of work. In some cases, where an unprofitable subfield is identified, the size or location of that subfield will not be practical for establishing an energy crop. Those areas may be best suited for conversion to a conservation practice (CRP, establishing a grass waterway or field border, etc.), whether enrolled in a government program or not. The key point is that the identified subfields are unprofitably farmed year after year, and it is worthwhile for the farmer to consider a management change that will limit or eliminate those losses (the management change could be as simple as reducing fertilization and seeding expenses in the identified unprofitable areas). Part of Iowa State University's scope of work for the project is to identify factors associated with whether or not a particular subfield would be profitable and practical to convert to a perennial energy crop. Ultimately, the farmer will consider management changes and change options based on their specific circumstances and preferences.
  - Reviewer Comment: It's not worth spending millions of dollars on planning to make hundreds in farming, and so, again, it's crucial to have a sense of how general the results being developed will prove to be.
  - Response: Developing the software and the underpinning modeling, calibrations, field demonstrations, field monitoring, data collection, and scientific reporting and publications is expensive. Those expenses are not necessary on an ongoing basis. Once developed, application of the tools is very affordable because it is a matter of defining field boundaries, collecting field-specific equipment data (where available), setting up the model parameters, and running a computer model—this can be performed by a trained expert crop management consultant working on behalf of the farmer. The fee for a one-year software license with technical support, allowing agri-business analysis for an entire farm enterprise (could be thousands of acres), is relatively nominal (several thousand dollars per year for a crop management consultant, and several hundred dollars per year for each farming operation served).

Previous Reviewers' Comments

- **Highlights from any Go/No-Go Reviews (From March 2018, Stage Gate Review)**
  - Reviewers at the March 2018 Stage Gate Review provided the following positive feedback regarding ORNL's contributions to this project: "The process for prioritizing and choosing relevant sustainability indicators is outstanding. The journal article published by Dale et al (provided to us during the review meeting) on this process and its outcomes is an important contribution to the literature on sustainability metrics. The team has gone to extraordinary and yet efficient means to engage a large number of organizations and stakeholders who would be impacted by the development of sustainable bioenergy and product supply chains in the targeted region of Iowa by taking advantage of multiple venues during 2015 and 2016. The analysis of the stakeholder feedback is intelligently and cogently presented, and is a model for others who wish to adopt a valid stakeholder engagement process." (ORNL, Parish)
  - The project aligns well with the FOA, and the proposed deliverables have promise to provide significant value to stakeholders involved, as well as the agricultural sector more generally. The breadth of stakeholders engaged is impressive, and appropriate means are being used to gather needs and feedback. The data, tools, and insights developed should be transferrable to food systems in general, not just biofuel crops.
  - This project is responsive to the changing bioeconomy. It continues to be relevant to both the FOA and stakeholders, despite loss of partners Abengoa and DuPont during the project period. The work being conducted in all tasks should help to enable the next generation of industry based on non-food crops while increasing the value and sustainability of commodity grain crops.
  - The tools, training and demonstration activities address the needs of stakeholders in the local landscape who want to proactively design their landscape for a sustainable future. The project leaders have assembled an outstanding team covering all of the required areas of expertise, representing contributions from government and academic researchers and, importantly, private sector entrepreneurs and farmers. This will ensure that its products and deliverables will be useful and relevant to both DOE and stakeholders.
  - The project has a high degree of focus on and commitment to achieving its goal of enabling design at the landscape level for a community-wide sustainable future. Much of this is due to the evident passion of the leadership team at Antares and at USDA. It is unfortunate that there is not a place in the review form to acknowledge this more intangible aspect of the project. While the project management we observed is clearly strong, it is the transformative nature of the project leadership that is found to be most exciting.

Previous Reviewers' Comments

- **Highlights from any Go/No-Go Reviews (From March 2018, Stage Gate Review)**
  - It is also very rewarding to see DOE's Bioenergy Technology Office take such a comprehensive and proactive approach to addressing the role that bioenergy can and must play in sustainable development. In this project, it is a demonstration on the part of BETO to take concrete steps to ensure its sustainability. Maintaining this commitment will always be difficult, especially in the face of increasing budget pressures. It is the hope that BETO and EERE management will continue to support these efforts, and encourage them to push for greater attention to the comprehensive challenges of sustainable development in the rest of its technology programs.
  - This task represents excellent leverage of the USDA soil science infrastructure and is conducting high-quality work at a scale that is likely to provide the first clear understanding of soil impacts from landscape design by using a paired field approach (powerful experimental design conducted at a real-world scale) and detailed soil and modeling analysis. The science is being conducted in close connection with other task, team and stakeholder members, ensuring broad dissemination and use of task findings.
  - The team presented an excellent and concise overview of progress on initial sampling efforts for baselining environmental indicators.
  - The AgSolver tool appears to offer an unprecedented level of granularity (approximately 9 square meter unit) in the assessment of crop field performance measured as profitability (return on investment). Recent efforts by USDA ARS's Ag Conservation Planning Framework team have resulted in what will ultimately be a valuable web tool that offers individual farmers the ability to explore specific opportunities within their farm operations to improve water quality in the context of the larger watershed. Used together, these two tools will allow farmers to balance trade-offs and identity win-win opportunities for increased profitability and long term stewardship of their watershed.
  - Almost more than any other project seen coming out of BETO, this project demonstrates a high degree of integration with other current and past research activities, particularly with regard to the extensive efforts at USDA locally (in the targeted landscape study area). The project is well-managed, and its leadership has developed an exceptional atmosphere of collaboration and commitment to the goals of the project. An intangible and yet important strength of this project is the level of energy and passion that permeates the team. This starts at the "top", with the PIs, who have communicated a powerful vision for the work. The level of cooperation between USDA and DOE is extraordinary.
  - Finally, a word of caution to the modelers and analysts—keep your eye on the prize. In this case that prize is a tool or set of tools that truly enables the users of these tools to efficiently and effectively make decisions that move the dial on sustainable development of the bioeconomy. No challenge is more difficult than this for analysts. There is a hard-to-achieve balance between rigor and robustness and the power and utility of simplicity. It is encouraged that you to spend some time planning for how these analytical tools will come together to meet the various needs of multiple end-users, from the technologically savvy user who will appreciate and actually make use of the details to the user whose focus is necessarily broader.

Previous Reviewers' Comments

- **Highlights from any Go/No-Go Reviews (From March 2018, Stage Gate Review)**
  - The one area where this project needs to focus more rigorously on is the ultimate usability of the decision support tool they are developing. This requires having the clearest possible understanding of the audience for this tool. It will be important to work throughout the modeling and development process WITH these users to ensure that this tool will be a catalyst for, and not obstacle to, good landscape design.
  - Finally, a word of caution to the modelers and analysts—keep your eye on the prize. In this case that prize is a tool or set of tools that truly enables the users of these tools to efficiently and effectively make decisions that move the dial on sustainable development of the bioeconomy. No challenge is more difficult than this for analysts. There is a hard-to-achieve balance between rigor and robustness and the power and utility of simplicity. It is encouraged that you to spend some time planning for how these analytical tools will come together to meet the various needs of multiple end-users, from the technologically savvy user who will appreciate and actually make use of the details to the user whose focus is necessarily broader.
  - The following comments are meant to further enhance the value delivered by the program… (1) The program needs a figure and a story that ties all of the deliverables together and shows them as a system, (2) More inclusion of national and international NGOs, like the ones involved in BMAS, might help diffuse knowledge to other sectors and countries, (3) Third party software developers should be invited to table now, as they can further the quality and adoption of better software tools, beyond that the current program can fund, (4) Build monetization methods into the environmental assessments as much as possible, (5) use operations research modeling to explore tradeoffs, (6) Final report should contain recommendations for broad adoption by growers.

Publications, Patents, Presentations, Awards, and Commercialization

30 Direct funded publications published, accepted, or under revision to date. 10 leveraged publications to date.

Directly Funded Publications: (reverse chronological order)

2020 Publications:

- Griffel, L. M., Vazhnik, V., Hartley, D. S., Hansen, J. K., and Roni, M. 2020. Agricultural field shape descriptors as predictors of field efficiency for perennial grass harvesting: An empirical proof. Computers and Electronics in Agriculture, 168. doi:10.1016/j.compag.2019.105088.
- Ha, M., Wu, M., Tomer, M. D., Gassman, P. W., Isenhart, T. M., Arnold, J. G., White, M. J., Comer, K. S. and Belden, B. 2020. Biomass Production with Conservation Practices for Two Iowa Watersheds. Journal American Water Resources Association. https://doi.org/10.1111/1752-1688.12880.
- Mamun, S., Hansen, J. K., and Roni, M. S. 2020. Supply, operational, and market risk reduction opportunities: Managing risk at a cellulosic biorefinery. Renewable and Sustainable Energy Reviews, 121. doi:10.1016/j.rser.2019.109677.
- Vazhnik, V. 2020. Farm Landscape Design Decision Support to Increase Economic, Environmental and Social Benefits Using Stakeholder Engagement, Sustainability Assessment and Spatial Analysis. Dissertation in BioRenewable Systems for The Pennsylvania State University. 230 pages.

2019 Publications:

- Griffel, M., Vazhnik, V., Hartley, D., Hansen, J., Richard, T. (2019). Machinery maneuvering efficiency and perennial crops: field shape complexity defines the efficiency. Manuscript in development.
- Hansen, J. K., Roni, M. S., Nair, S. K., Hartley, D. S., Griffel, L. M., Vazhnik, V., and Mamun, S. 2019. Setting a baseline for Integrated Landscape Design: Cost and risk assessment in herbaceous feedstock supply chains. Biomass and Bioenergy, 130. doi:10.1016/j.biombioe.2019.105388.
- Hansen, J.K, Nair, S.K., Roni, M.S., Hartley, D.S., Griffel, L.M., Vazhnik, V. & Mamun, S. (2019). Herbaceous feedstock supply chain cost risk assessment. Submission to Biomass and Bioenergy.

Publications, Patents, Presentations, Awards, and Commercialization

Directly Funded Publications, continued: (reverse chronological order)

2019 Publications (cont.):

- Jin, V. L., Schmer, M. R., Stewart, C. E., Mitchell, R. B., Williams, C. O., Wienhold, B. J., Varvel, G. E., Follett, R. F., Kimble, J., and Vogel, K. P. 2019. Management controls the net greenhouse gas outcomes of growing bioenergy feedstocks on marginally productive croplands. Science Advances. Vol. 5, no. 12, eaav9318. DOI: 10.1126/sciadv.aav9318.
- Karlen, D. L., Schmer, M. R., Kaffka, S. R., Clay, D. E., Wang, M. Q., Horwath, W. R., Kendall, A. M., Keller, A., Pieper, B. J., Unnasch, S., Darlington, T., Vocasek, F. and Chute, A. G. 2019. Unraveling Crop Residue Harvest Effects on Soil Organic Carbon. Agronomy Journal 111:93-98. https://doi:10.2134/agronj2018.03.0207
- Kreig, J. F. A., Chaubey, I., Ssesane, H., Negri, C. M.. and Jager, H. I. 2019. Designing bioenergy landscapes to protect water quality. Biomass & Bioenergy 128 105327.
- Malone, R. W., Herbstritt, S., Ma, L., Richard, T. L., Cibin, R., Gassman, P. W., Zhang, H. H., Karlen, D. L., Hatfield, J. L., Obrycki, J. F., Helmers, M. J., Jaynes, D. B., Kaspar, T. C., Parkin, T. B., and Fang, Q. X. 2019. Corn stover harvest N and energy budgets in central Iowa. Science of the Total Environment. 63:776-792. https://doi.org/10.1016/j.scitotenv.2019.01.3280048-9697
- Xu, H., Sieverding, H., Kwon, H., Clay, D., Stewart, C., Johnson, J. M. F., Qin, Z., Karlen, D. L., and Wang, M. 2019. A global meta-analysis of soil organic carbon response to corn stover removal. Global Change Biology – Bioenergy 11, 1215-1233. 10.1111/gcbb.12631

2018 Publications:

- Dale et al. (2018) Bridging biofuel sustainability indicators and ecosystem services through stakeholder engagement. Biomass and Bioenergy 114:143-156.
- Jager HI and Kreig JAF (2018) Designing landscapes for biomass production and wildlife. Global Ecology and Conservation 16:e00490.
- Johnson, J. M. F. and Barbour, N.W. 2018. Stover harvest did not change nitrous oxide emissions in two Minnesota fields. Agronomy Journal. 111:143–155.
- Karlen, D. L. and Obrycki, J. F. Measuring rotation and manure effects in an Iowa farm soil health assessment. Agronomy Journal. 110:749-757. 2018. https://doi.10.2134/agronj2018.02.0113

Publications, Patents, Presentations, Awards, and Commercialization

Directly Funded Publications, continued: (reverse chronological order)

2018 Publications (cont.):

- Karlen DL, JF Obrycki. 2018. Measuring rotation and manure effects in an Iowa farm soil health assessment. Agron. J. 111:63-73. doi:10.2134/agronj2018.02.0113
- Malone, R. W., Obrycki, J. F, Karlen, D. L., Ma, L., Kaspar, T. C., Jaynes, D. B., Parkin, T. B., Lence, S. H., Feyereisen, G. W., Fang, Q. X., Richard, T. L., and Gillette, K. 2018. Harvesting fertilized rye cover crop: Simulated revenue, net energy, and drainage nitrogen loss. Agricultural and Environmental Research Letters 3:170041. https://doi:10.2134/ael2017.11.0041
- Obrycki, J. F., Kovar, J. L., Karlen, D. L., and Birrell, S. J. 2018. Ten-year assessment encourages no-till for corn grain and stover harvest. Agricultural & Environmental Letters. 3:180034. https://doi:10.2134/ael2018.06.0034
- Obrycki, J. F. and Karlen, D. L. 2018. Optimizing Iowa land use: Past perspectives for current questions. Journal of Soil and Water Conservation 73:693-704. https://doi:10.2489/jswc.73.6.693
- Obrycki, J. F. and Karlen, D. L. 2018. Is Corn Stover Harvest Predictable Using Farm Operation, Technology, and Management Variables? Agronomy Journal. 110:749–757. https://10.2134/agronj2017.08.0504
- Obrycki JF, DL Karlen. 2018. Optimizing Iowa land use: Past perspectives for current questions. J. Soil Water Conserv. 73:693-704. doi: 10.2489/jswc.73.6.693
- Obrycki JF, DL Karlen, CA Cambardella, JL Kovar, SJ Birrell. 2018. Corn stover harvest, tillage, and cover crop effects on soil health indicators. Soil Sci. Soc. Am. J. 82:910-918. doi:10.2136/sssaj2017.12.0415
- Parish, E., Dale, V., Davis, M., Efroymson, R., Hilliard, M., Jager, H., Kline, K., and Xie, F. In Press. An indicator-based approach to sustainable management of natural resources. Chapter 13 in Data Science Applied to Sustainability Analysis. Edited by Dunn, J. and Balaprakash, P. Elsevier DOI: 10.1016/C2018-0-02415-9
- Reichmann, L. G., Collins, H. P., Jin, V. L., Johnson, M-V. V., Kiniry, J. R., Mitchell, R.B., Polley, H. W., and Fay, P. A. 2018. Inter-annual precipitation variability decreases switchgrass productivity from arid to mesic environments. Bioenergy Research 11: 614-622.

Publications, Patents, Presentations, Awards, and Commercialization

Directly Funded Publications, continued: (reverse chronological order)

2018 Publications (cont.):

- Sharma B, Clark R, Hilliard MR, Webb EG (2018) Simulation modeling for reliable biomass supply chain design under operational disruptions. Frontiers in Energy Research 6:100. doi: 10.3389/fenrg.2018.00100
- Stetson, S. J., Lehman, R. M. and Osborne, S. L. 2018. Corn residue particle size impacts soil surface properties. Agricultural and Environmental Letters. 3:180004 doi:10.2134/ael2018.01.0004.

2017 Publications:

- Jin, V. L., Schmer, M. R., Stewart, C. E., Sindelar, A. J., Varvel, G. E., and Wienhold, B. J. 2017. Long-term no-till and stover retention each decrease the global warming potential of irrigated continuous corn. Global Change Biology. 23:2848-2862.
- Schmer, M. R., Brown, R. M., Jin, V. L., Mitchell, R., and Redfearn, D. D. 2017. Corn residue utilization by livestock in the USA. Agricultural and Environmental Letters. 2:160043.

2016 Publications:

- Kanter, D. R., Musumba, M., Wood, S. L. R., Palm, C., Antlee, J., Balvanera, P., Dale, V. H., Havlik, P., Kline K. L., Scholes, R. J., Thornton, P., Tittonellk, P., and Andelman, S. 2016. Evaluating agricultural trade-offs in the age of sustainable development. Agricultural Systems. https://www.researchgate.net/publication/309230139

Publications, Patents, Presentations, Awards, and Commercialization (cont.)

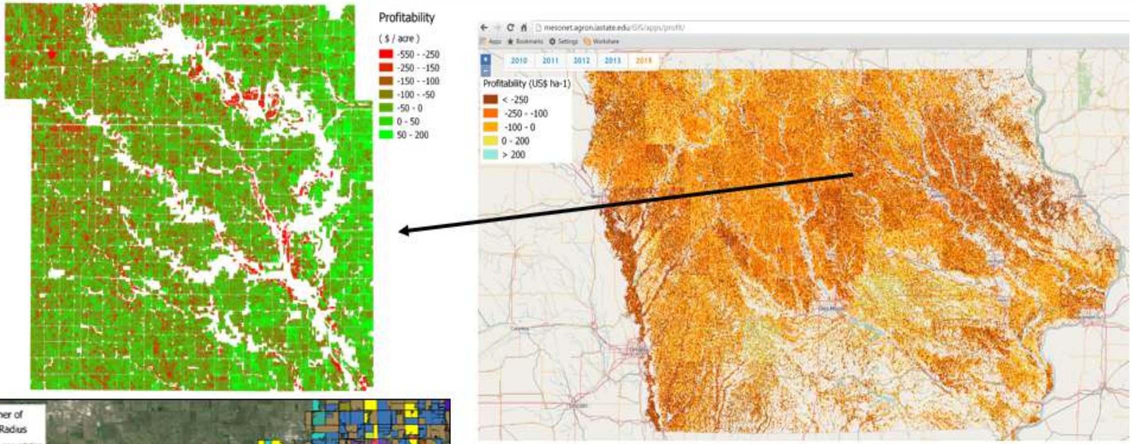
Leveraged Publications (co-author is a member of our project team and the publication is related to our project activities and subject matter, but the publication was not directly funded by this project):

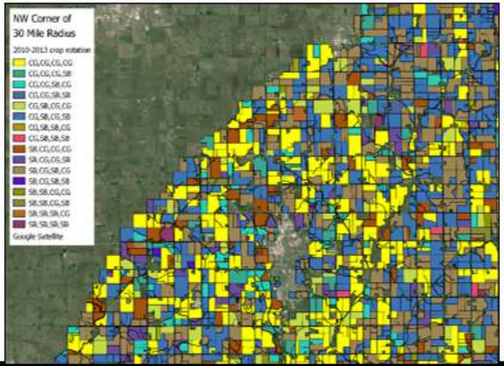
- Dien BS, Mitchell RB, Bowman MJ, Jin VL, Quarterman J, Schmer MR, Singh V, Slininiger PJ. 2018. Bioconversion of pelletized big bluestem, switchgrass, and low-diversity grass mixtures into sugars and bioethanol. Frontiers Energ. Res. 6: Article 129. doi.org/10.3389/fenrg.2018.00129
- Ibrahim VE, SL Osborne, TE Schumacher, WE Riedell. 2018. Corn residue removal effects on hydraulically effective macropores. Comm. Soil Sci. Plant Anal. 49:1491-1501. doi.org/10.1080/00103624.2018.1464187
- Jin VL, MR Schmer, CE Stewart, B Mitchell, CO Williams, BJ Wienhold, GE Varvel, RF Follett, J Kimble, KP Vogel. Perennial feedstocks on marginally-productive land contribute to climate mitigation goals. Science Advances. Revision pending.
- Locker CR, Laurenzi IJ, Torkamani S, Jin VL, Schmer MR, Karlen DL. 2019. Field-to-farm gate greenhouse gas emissions from corn stover production in the Midwestern U.S. Journal of Cleaner Production. Accepted February 2019.
- Sindelar M, Blanco H, Jin VL, Ferguson R. 2019. Cover crops and corn residue removal: impacts on soil hydraulic properties and their relationships with carbon. Soil Sci. Soc. Am. J. doi:10.2136/sssaj2018.06.0225
- Sindelar M, Blanco H, Jin VL, Ferguson R. 2019. Do cover crops and corn residue removal affect soil thermal properties? Soil Sci. Soc. Am. J. Accepted November 2018.
- Stetson SJ, RM Lehman, SL Osborne. 2018. Corn residue particle size impacts soil surface properties. Agric. Environ. Lett. 3:180004 doi:10.2134/ael2018.01.0004.
- Stewart CE, D Roosendaal, AJ Sindelar, E Pruessner, VL Jin, MR Schmer. Does no-tillage mitigate stover removal in irrigated continuous corn? A multi-location assessment. Soil Sci. Soc. Am. J. Accepted Feb 13, 2019.
- Stewart CS, Roosendaal DL, Sindelar A, Pruessner E, Jin VL, Schmer MR. 2018. Soil property changes from stover removal under irrigation: a multi-location assessment. Soil Science Society of America Journal. In Review.
- Wegner BR, SL Osborne, RM Lehman, S Kumar. 2018. Seven-year impact of cover crops on soil health when corn residue is removed. BioEnerg. Res. 11:1-9. doi.org/10.1007/s12155-017-9891-y.

BACK-UP SLIDES

1 – Project Overview

Identifying the Impact and Opportunity





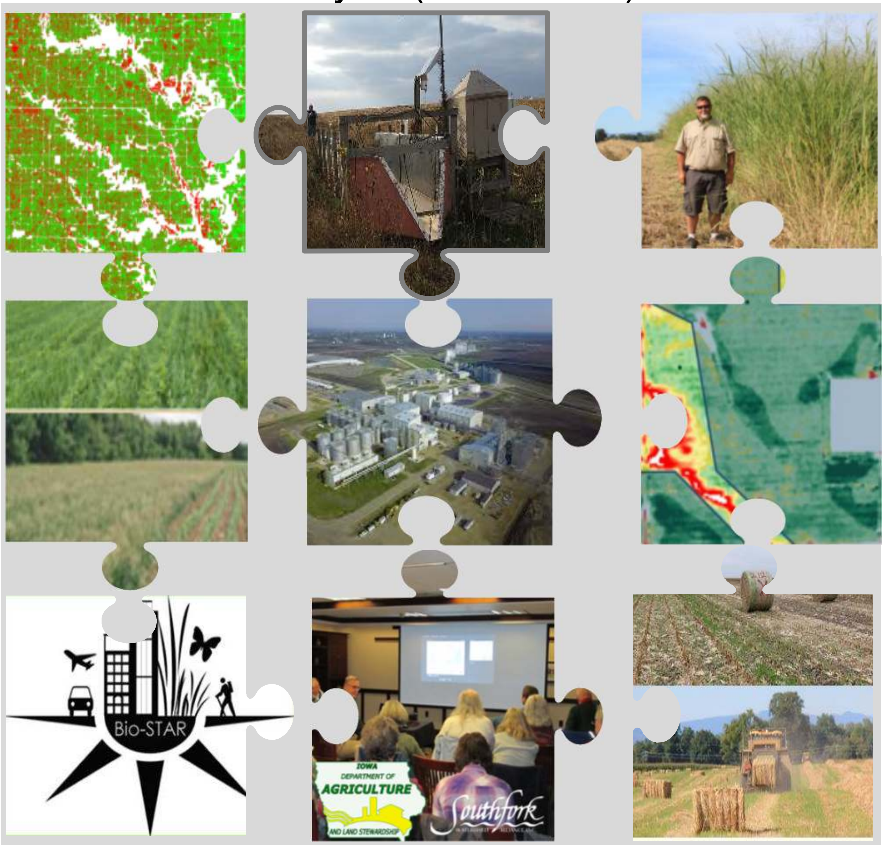
- Between 2-3 million acres annually at an expected loss
- Over $1B annually in misallocated working capital

All linked to increased profits, biomass supplies, and key sustainability indicators.

Field Sampling
& Analysis (USDA ARS)

Regional
Impact
Modeling &
Monitoring

Perennial
Grass for
Conservation &
Biomass
Supply from
Marginal Lands



Implementation
of Conservation
Practices (Cover
Crops, Saturated
Buffers, etc.)

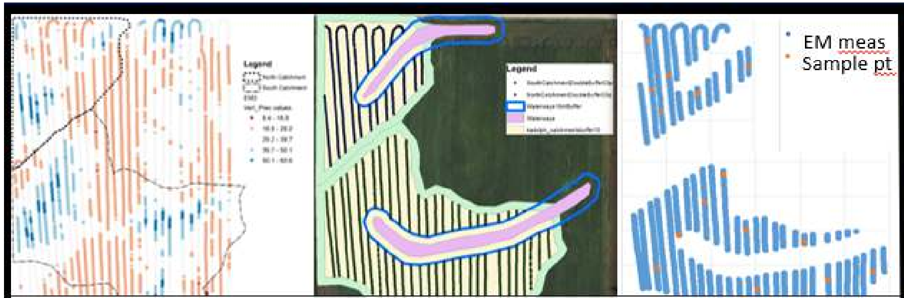
Subfield
Precision
Business
Planning
(Profit-
focused)

Sustainability
Indicators:
Soil Health, Nutrient
Run-off, Wildlife
Biodiversity, GHG
Emissions, Other

Sustainable
Residue &
Perennial Grass
Harvest

Multi-stakeholder Outreach

Task 5 – Environmental Assessment



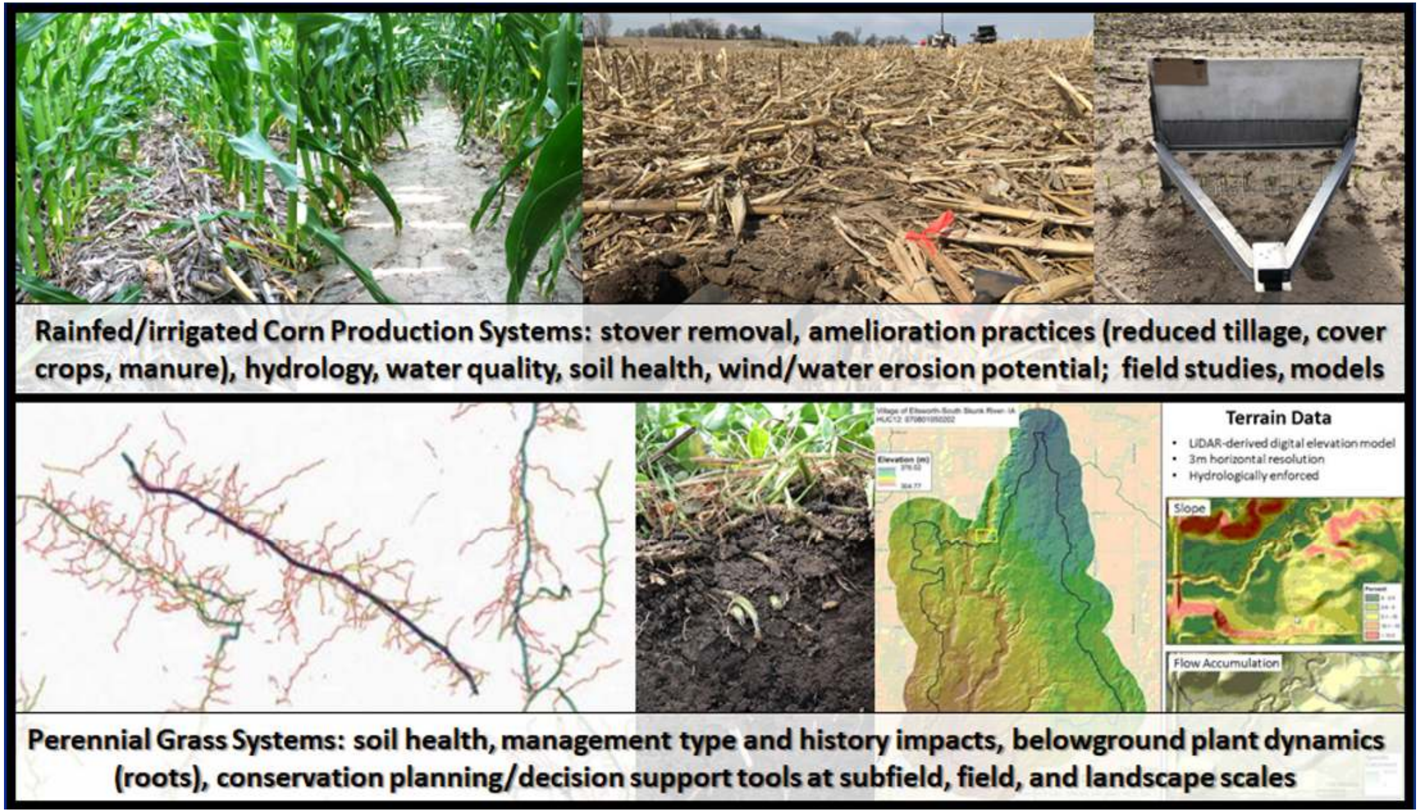
Rainfed corn: Stover removal, hydrology, water quality, soil health (IA) – Instrumented catchments, field studies, watershed models

Irrigated corn: Wind erosion, soil health (KS, CO) - Field studies, erosion models

Perennial grasses: Soil health and land use change impacts on marginal farmlands (IA) – Field studies, conservation management

Decision support tools: Sustainability for field, farm, and landscape (ACPF, AgSolver)

Task 5 – Environmental Assessment



3 - Accomplishments

Assessments: On-farm catchments + 38 fields on 15 farms (IA), 3 research farms in KS & CO

New on-farm conservation practices for stover mgt (IA)

Saturated buffer network in Southfork watershed (IA)

Leveraging new studies on bioenergy switchgrass production potential on marginal lands; quantifying land use impacts on belowground root inputs; stakeholder meetings on soil health, conservation practices, bioenergy

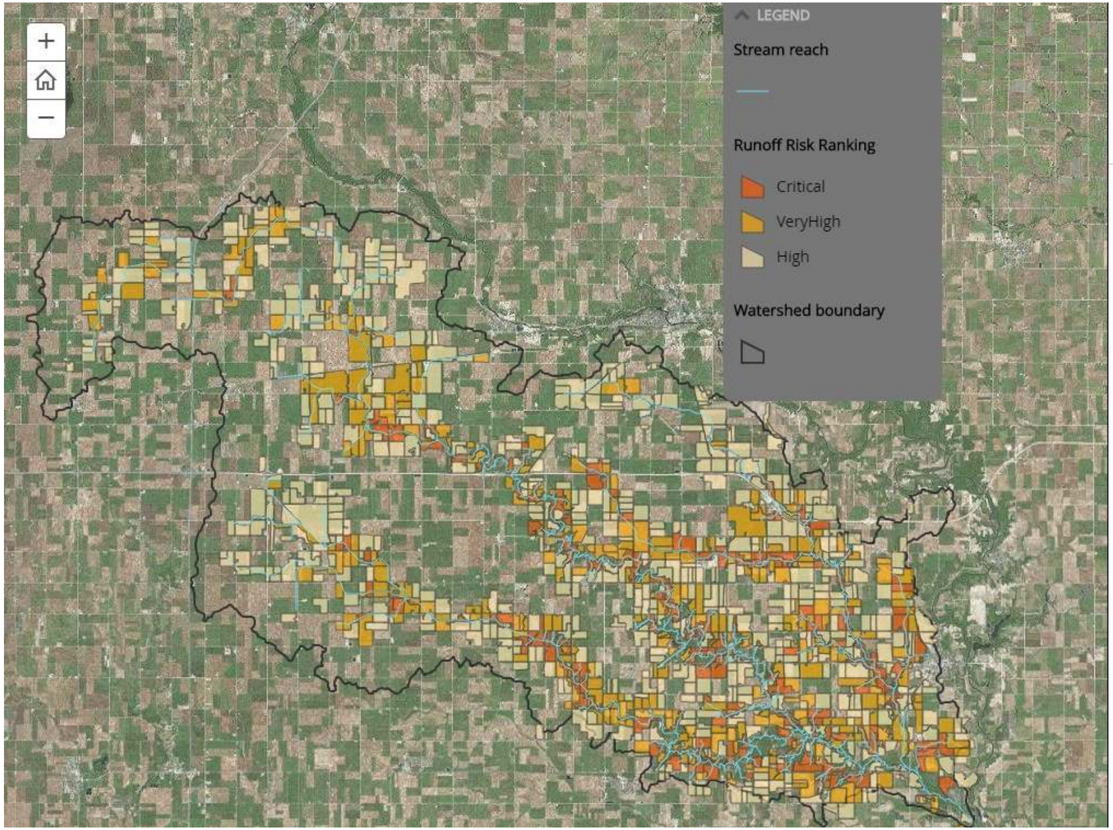
USDA United States Department of Agriculture
Agricultural Research Service

Accomplishments & Future Plans

Landowner soil health reports; peer-reviewed manuscripts on soil health, root dynamics, erosion potential, recommendations for stover management, improvement of conservation planning tools and adoption

Leveraging new studies on targeted switchgrass production in marginal and multi-use landscapes (bioenergy, grain, livestock); impacts on soil health, water quality/quantity, wildlife, and greenhouse gas emissions

Landscape Analysis Tools



South Fork Watershed & The USDA

A Menu of Conservation Practice Opportunities in the South Fork of the Iowa River

greater may still be impacted by runoff, this is merely a suggestion.

Runoff Risk Assessment:
Prioritize fields where multiple erosion control practices are most needed

Close to stream?

Slope steepness	Yes		No
H	A	B	C
M	B	C	
L	C		

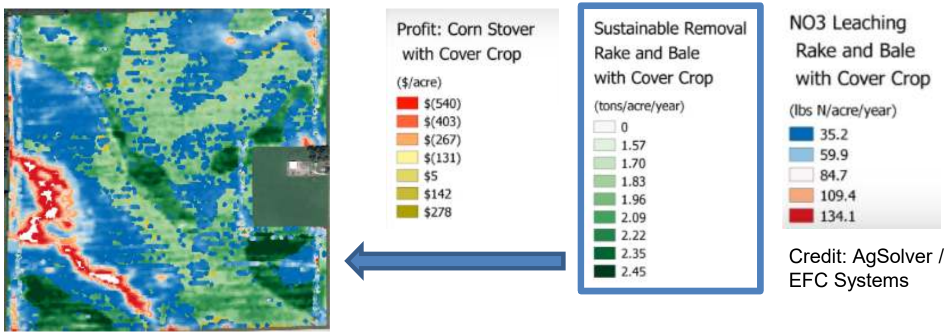
Drainage Water Management

The inset map below shows a suitable area for drainage water management between the South Fork and Tipton Creek channels. This is a relatively flat area within the watershed, making it ideal for drainage management

Tools such as the Agricultural Conservation Planning Framework (ACPF) are being used to Identify potential sites Landscape Design changes. In this case, the nutrient runoff risk is being assessed for the Southfork watershed.

Straeter Header: Sustainable, Variable-Rate Harvest

- Real-time sustainability calculations in the field based on:
  - User inputs, corn yield, field conditions (soil type, slope, etc.)
- Reduces the need for overly conservative stover removal protocols that result in harvested stover yields of ~1 ton/acre



Credit: AgSolver / EFC Systems

Advanced Data Analytics + Advances in Machine & Controls Technology and Feedstock Logistics = Improved: Sustainability, Biomass Supply Potential, Economics

Virginia Switchgrass Harvests

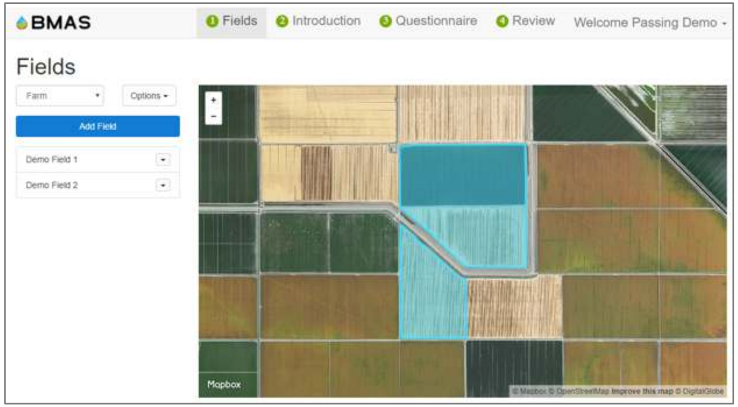
- 600 to ~ 2,000+ acres per year, 5 years
- Used as proxy for Iowa "subfield" perennial grass harvest situation
- Part of existing switchgrass-to-boiler-fuel operating supply chain (very rare)

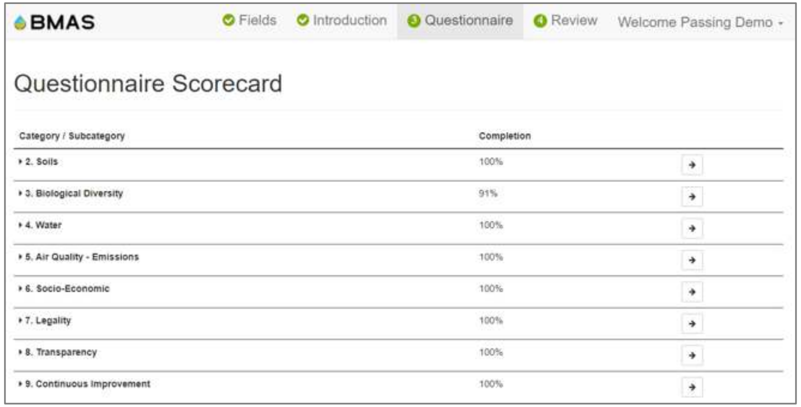


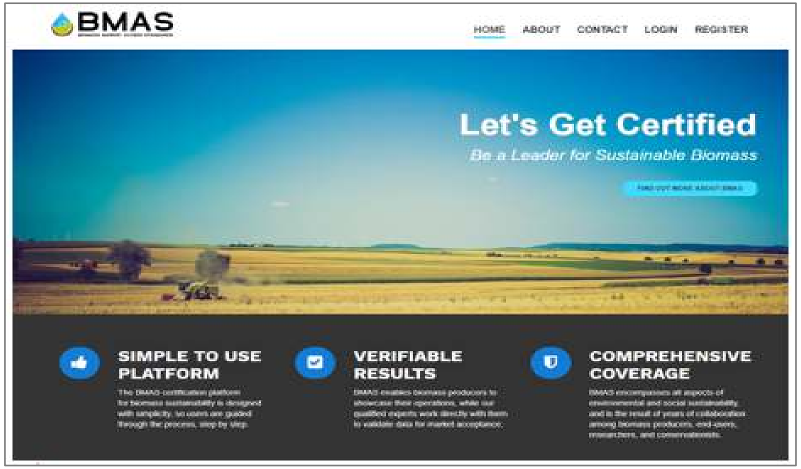




Web-based Sustainability Platform







Continuous Improvement System

- TurboTax-style Sustainability Certification Platform

BMAS Interface Framework