MARCH 10, 2021

DATA, MODELING, AND ANALYSIS SESSION

DOE BIOENERGY TECHNOLOGIES OFFICE (BETO) 2021 PROJECT PEER REVIEW

SCALING UP THE ECOSYSTEM SERVICES OF BIOENERGY LANDSCAPES

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U.S. DEPARTMENT OF ENERGY
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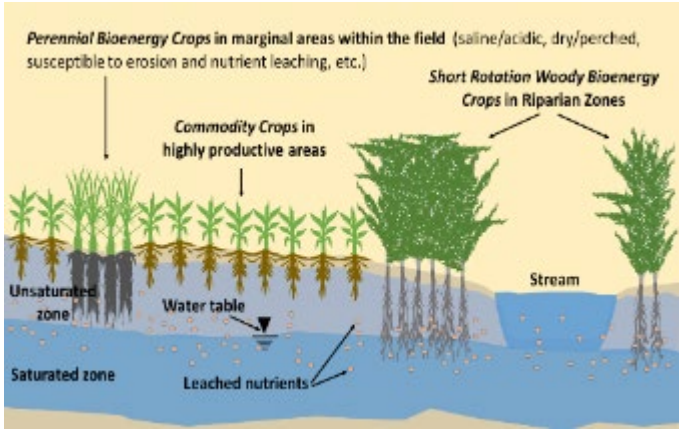
Argonne NATIONAL LABORATORY 75 1946–2021

PROJECT OVERVIEW

- This project recognizes the effect that perennial bioenergy crops can have by
  - Providing an additional crop with low input (fertilizer, water) requirements
  - Providing ecosystem services, which may themselves have economic value



Source: Cacho et al. 2017

- Furthermore, by integrating perennials into economically and/or environmentally marginal farmland, land use change is minimized, as is the effect on commodity crop production.
- Farmer? Win. Environment? Win. Bioeconomy? Win.
- 3-year project (FY20-FY22)
  - Initial funding received and project begun January 2020
  - Builds upon prior BETO-funded efforts in ecosystem services quantification and valuation (field and lab, landscape design, modeling, economics)
  - Key components are a geospatial tool for decision-making, with supporting technology evaluation and economic analysis, and long-term observatory data
  - Regarding risk, the success of this vision depends in the end on a viable market for feedstock and ecosystem services

1 – MANAGEMENT

Our project is focused on 3 tasks, with a multidisciplinary set of staff working collaboratively:

- Cristina Negri – overall direction and guidance
- John Quinn – project management, technical development of geospatial tool
- Jules Cacho – technical development of geospatial tool, remote sensing
- Colleen Zumpf – Fairbury observatory, remote sensing
- Andy Ayers – programming specialist, technical development of geospatial tool
- Jim Kuiper – GIS specialist, technical development of geospatial tool
- Yuki Hamada – remote sensing specialist
- Nora Grasse – Fairbury observatory, techno-economic analysis
- Postdoc (pending) – demand analysis

Risks are considered internally as a team

- Through a series of discussions, refined approach for remote sensing as a component of the geospatial tool.

Communications with BETO and other National Labs

- Monthly meetings, working groups, and other forums.

Communication and collaborations with academia and industry

- Several related BETO projects (FOA awards), each being distinct in their approach, technology, goals, and geographic focus:
  - *ASEC* -Affordable and Sustainable Energy Crops - University of Illinois (UIUC, lead), Iowa State, USDA-ARS, South Dakota State
  - *EC-BioSALTS* - Evaluation of Energycane for Bioenergy and Sustainable Agricultural Systems - with University of Florida (lead) (new in FY21)
  - *EXCHANGE:* EXpanding the Conversion of HAbitat in the Northern Great Plains Ecosystem - with University of Nebraska (lead) and USDA-ARS (new in FY21)

2 – APPROACH

A key comment from the 2019 Peer Review of our prior BETO project was whether we could apply the findings from our Illinois field site more broadly. This was a driver for the current project's scope.

The key deliverable of this project is a geospatial tool with 3 capabilities:

- To scale up the delineation of economically and/or environmentally **marginal land** based on a range of factors
- To quantify the **ecosystem services** to be achieved by conversion of marginal land to perennial bioenergy crops, such as water quality, water quantity, GHG, C sequestration, biodiversity
- To provide an estimate of the **economic valuation** of these ecosystem services in the selected study area

And the name of this tool is…

SCALING UP PERENNIAL BIOENERGY ECONOMICS AND ECOSYSTEM SERVICES TOOL (SUPERBEEST)

Based on watershed-scale assessment in Illinois during prior project

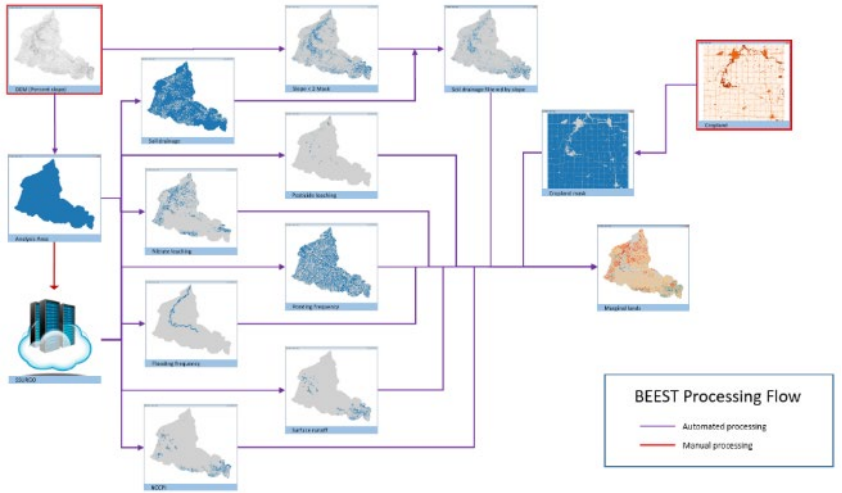
12 Midwest states domain

Analysis at any scale

- County/counties,
- HUC8 (8-digit hydrologic unit code) to HUC12 watershed(s), or
- user-defined polygon (e.g. individual farm)

Intended users:

- agencies, producers (farmers), researchers, regulators, industry



OTHER COMPONENTS

Refine remote sensing technology to determine economic marginality in irrigated regions where NCCPI information is not applicable - A technical challenge to relating imagery to observatory calibration data

Limited long-term trend evaluations at our Fairbury, Illinois observatory

A demand analysis to understand drivers for adoption and potential trading schemes

- – Focus on key ecosystem services aspect of water quality - economic drivers for water treatment facilities
- – Price-point determination for decision-making
- – Pursue our collaborations with the Metropolitan Water Reclamation District of Greater Chicago (MWRD), the Vermillion Headwaters (IL) team, the Illinois Nutrient Loss Reduction Strategy team, and others

Water treatment facility

3 – IMPACT

- **A thriving Bioeconomy** –increased adoption, and reduced feedstock production cost
- **The Environment** –improved water quality, biodiversity, and carbon sequestration, decreased greenhouse gas (GHG) emissions and topsoil loss
- **Producers** – farmers' need for optimal cropping systems, low input (e.g. fertilizer) cost, and a resilient and stable rural economy

SUPERBEEST contributes toward all these needs:

- Identifying marginal land, ecosystem services and total economic of a conversion to perennials, including ES demand analysis
- A free, online tool, and webinars, publications, conference presentations, and training.

Addressing:

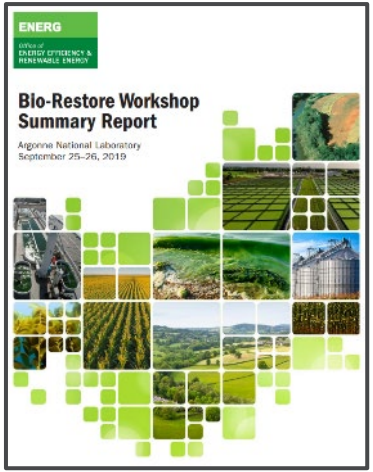
MYP Milestone 19AS22: Verify landscape-design approaches for at least one bioenergy system that, when compared to the conventional agricultural and logistics systems, will increase practical agricultural biomass supply availability by 100% or more on a per acre basis, while maintaining or enhancing ecosystem services.

Barriers:
At-B: Analytical Tools and Capabilities for System-Level Analysis
At-E: Quantification of Economic, Environmental, and Other Benefits and Costs
At-F: Science-Based Methods for Improving Sustainability

4 – PROGRESS AND OUTCOMES

Precursor project: Accomplishments since 2019 Peer Review

- Field work at the Fairbury, IL observatory
  - Annual monitoring of soil organic matter content for validating an earlier uptrend in subsoil carbon content
  - Biodiversity studies - microbes, insects, native plants, native prairie grasses
- Valuation of ecosystem services
- Electronic poster



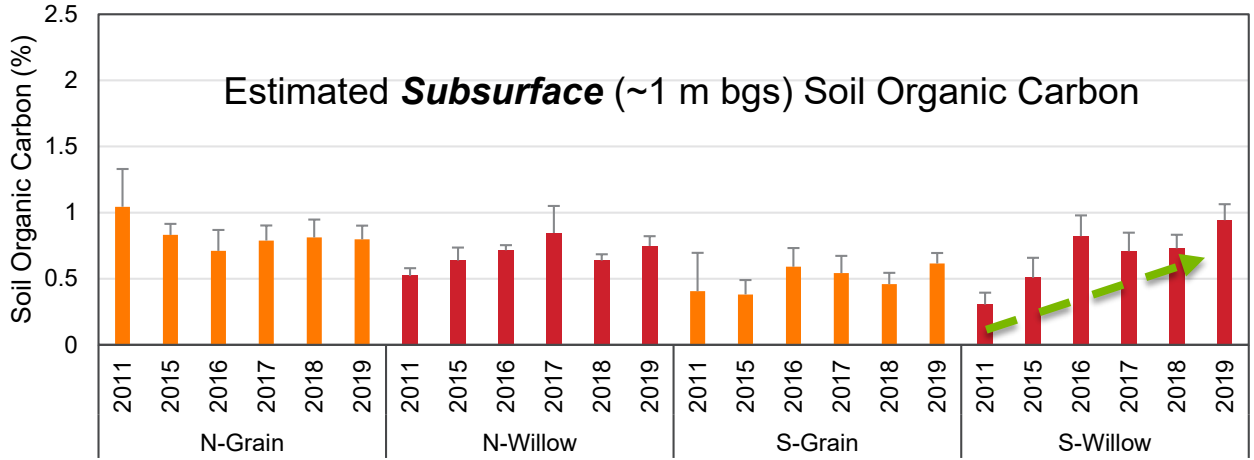
In addition, we supported BETO in hosting a workshop: DOE BETO Bio-Restore Workshop, September 25-26, 2019 at Argonne National Laboratory and prepared most of the summary report.

Current project scope:

- Model development (completed the SUPERBEEST component for analyzing land marginality. Go/No-Go resolution)
- Addressing tile drains and saturated buffers

FIELD: POTENTIAL SUBSOIL CARBON SEQUESTRATION

- At Fairbury observatory, annual subsoil organic carbon content data (from 4 ft below the soil surface) indicates potential subsoil carbon increases
  - Evaluating long-term trend
  - Also measuring biomass production over additional harvest cycles
- Sole Midwest site for willow, with both marginal and non-marginal locations



BIODIVERSITY IN THE FIELD – PLANTS AND INVERTEBRATES

Results:

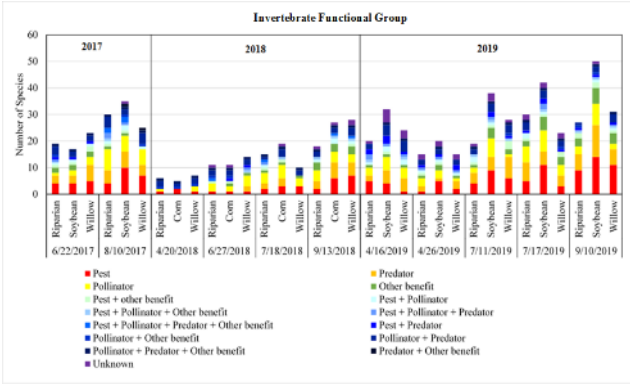
- Plants:
  - Willow plots generally had higher understory plant diversity and richness than grain plots and supported the largest number of unique species (species observed only within that landcover type during the study period)
    - Over 60% of the species were native species
  - All landcovers supported distinct communities (based on species presence and abundance)

- Invertebrates:
  - Invertebrate communities were similar among landcovers and varied more by sample timing during the season
  - Willow plots supported several unique species; however, willow plots generally had lower diversity and richness than grain plots
  - All landcovers supported species from a range of functional groups (pest, pollinator, and predators)

Conclusions:

The presence of unique species of invertebrate and plant species suggest that willows can support biodiversity in this type of design.

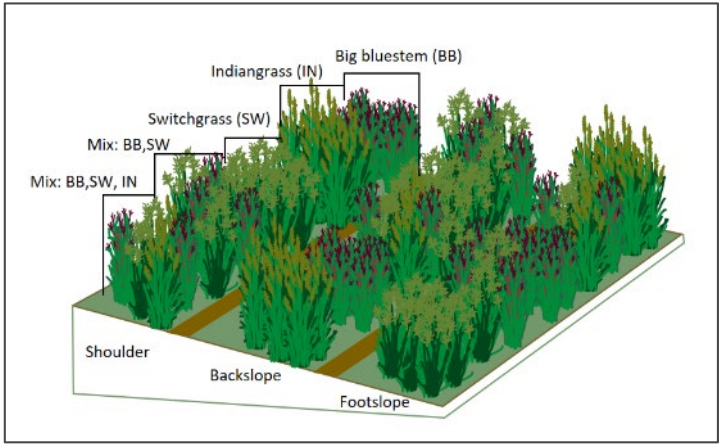
Results also highlight the importance of habitat heterogeneity, in general, to support species throughout the season.

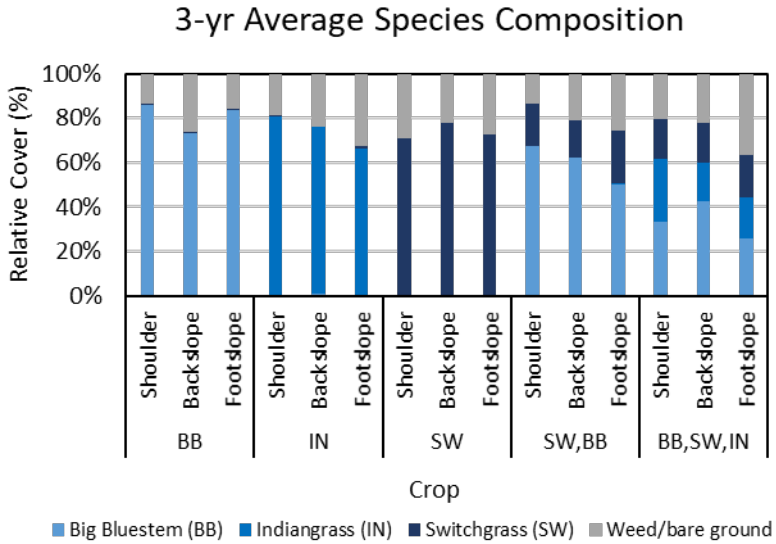


Zumpf, C., J. Quinn, J. Cacho, N. Grasse, P. Campbell, M.C. Negri, D.K. Lee., (under internal review), Invertebrate and plant community diversity of an Illinois Corn-Soybean field with Integrated Shrub Willow Bioenergy Buffers.

NATIVE GRASSES – FAIRBURY SITE

- In addition to shrub willow, we are evaluating biomass production of native warm-season grasses (Big bluestem, Indiangrass, and Switchgrass) in monocultures and mixtures on three slope gradient positions.
- Collaboration with UIUC (D.K. Lee)



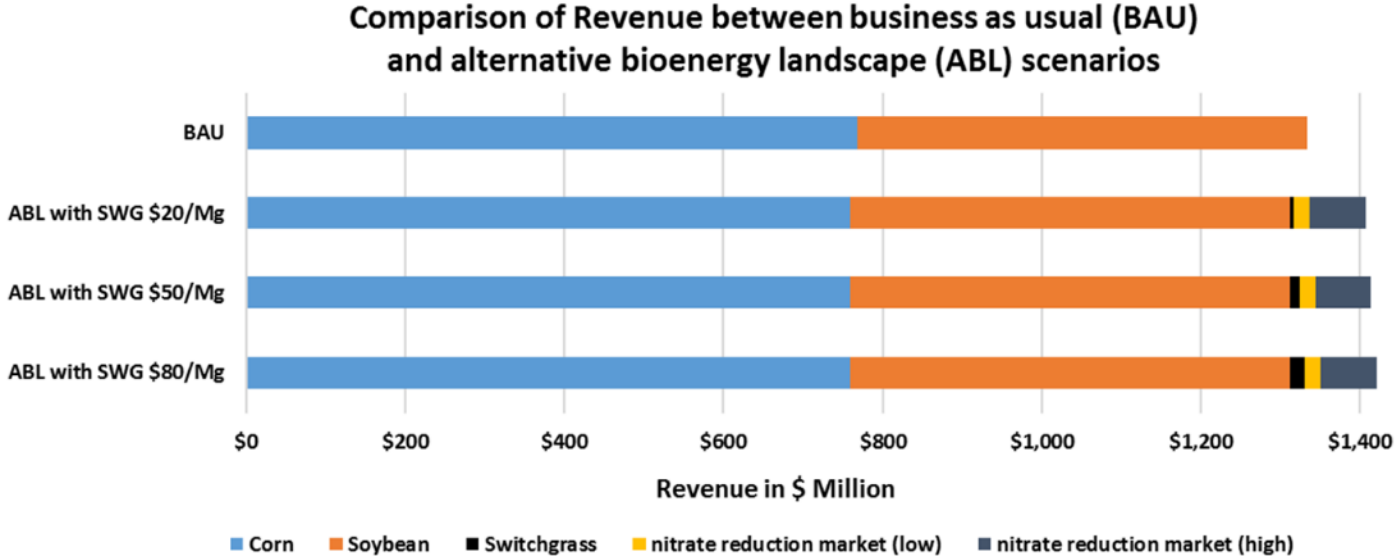


Preliminary Conclusions:

- Gradient position may have an impact on biomass yield potential
- Across gradient positions and sampling years, all species (monoculture/mixed) produced numerically similar biomass yields
- Big bluestem seemed to dominate when mixed with switchgrass and Indiangrass, which may be due to the dry, gravelly soil conditions
- Marginality may be different across species (willow did not thrive in this area).

ECOSYSTEM SERVICES VALUATION – UPPER VERMILLION BASIN, ILLINOIS

- 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 (e.g., nitrate loss reduction; decreased soil erosion and GHG emissions; enhanced water-based recreation, wildlife viewing, hunting, and pollinator services benefits)
- Value of reduced nitrate ***alone*** would create a net gain of $20 to $90 million, depending on market for nitrate reduction (as shown below)



Source: data from Mishra et al., 2019, Valuation of Ecosystem Services in Alternative Bioenergy Landscape Scenarios: Global Change Biology Bioenergy,11:748–762.

ELECTRONIC POSTER

We created a website as an “electronic poster”, showcasing group efforts in ecosystem services

- https://web.evs.anl.gov/bioenergy/
- Publications and other info organized by theme
- A living repository for our research group

Electronic poster gateway

4 – PROGRESS AND OUTCOMES (CONT.)

We are approximately one year into the current project. Accomplishments so far (shown on next slides) are

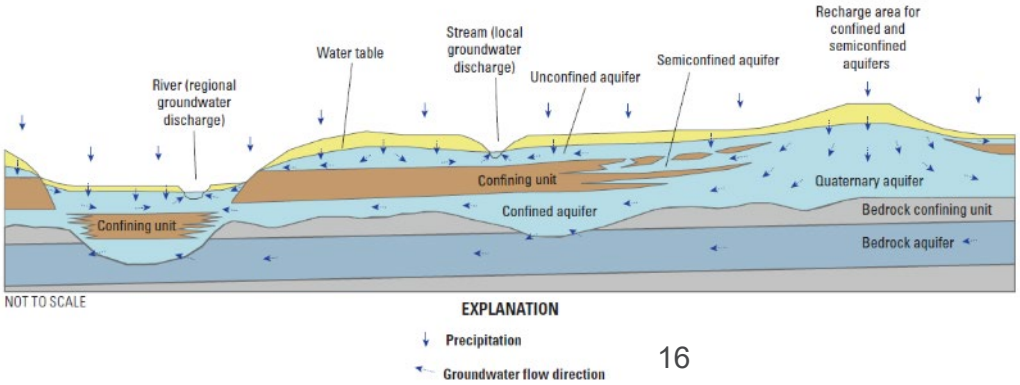
- Resolving Go/No-Go decision point related to the paucity of data on nitrate and pesticide leaching potential as an important environmental marginality metric
- SUPERBEEST agricultural land marginality classification capability
- Saturated bioenergy buffer analysis

In addition, we are progressing on the evaluation of remote sensing technology to evaluate economic marginality in irrigated regions where SSURGO information is not applicable.

GO/NO-GO DECISION POINT

- SUPERBEEST includes a wide range of factors for evaluating marginal land:
  - *Crop productivity* (NCCPI - National Commodity Crop Productivity Index)
  - *Environmental factors*: Ponding, flooding, drainage, runoff (all SSURGO), and **leaching** of nitrate and pesticide to groundwater
  - SUPERBEEST could determine multiple marginality factors for most optimal locations for perennial bioenergy crops

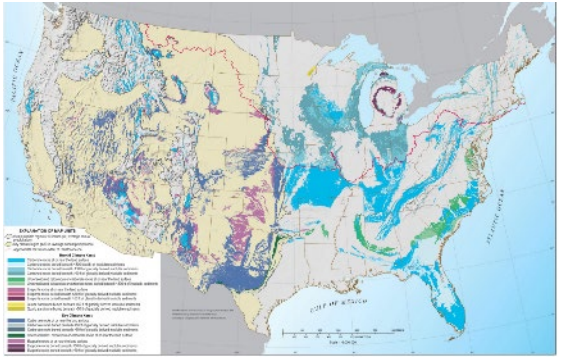
- **Go/No-Go**: Can leaching and aquifer susceptibility be addressed properly and consistently? Highly complex and under-characterized hydrogeologic framework across the Midwest a concern.



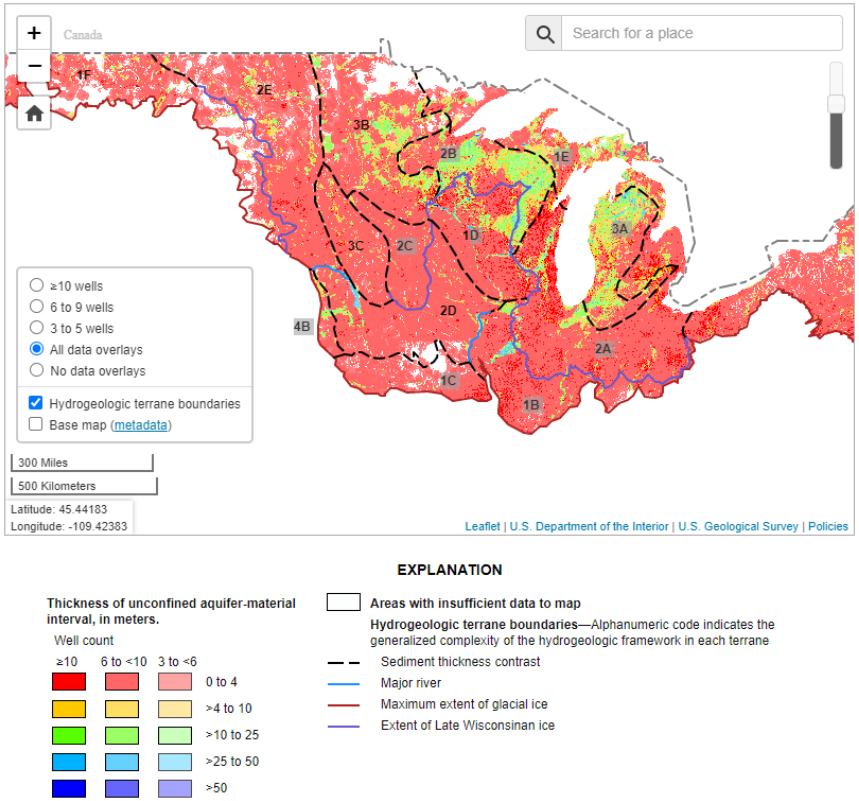
Conceptual diagram of unconfined, semiconfined, and confined aquifers and local to regional flow systems in Midwest Quaternary sediments and sedimentary bedrock (Source: USGS - Yager et al. 2019)

GO/NO-GO (CONT.)

- Solution involved interpretation of a USGS spatial database of 1.5 million well drilling logs, combined with another USGS database on karst features, and SSURGO info on surficial soil organic matter (for pesticide analysis)
  - Consistent approach throughout Midwest
  - “Go”



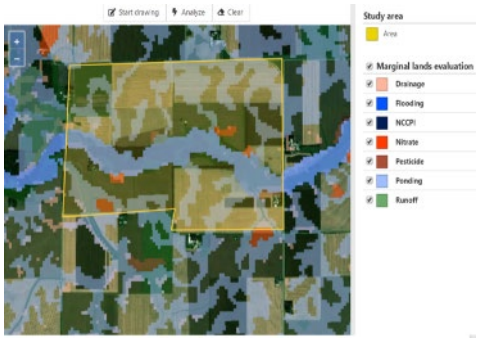
Karst and potential karst areas in soluble rocks in the U.S. (source: USGS - Weary and Doctor 2014)



Thickness of unconfined (surficial) Quaternary aquifers in the Midwest (source: modified from USGS - Yager et al. 2020).

SUPERBEEST OUTPUT TO DATE

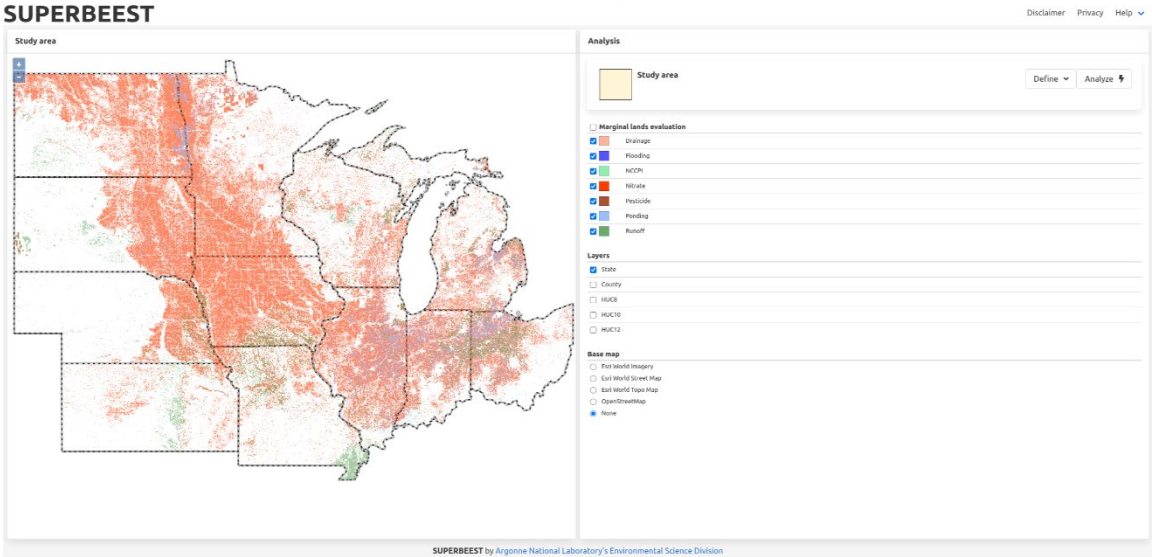
Example of farm scale (user-defined polygon)



Marginality analytical capability

We have incorporated

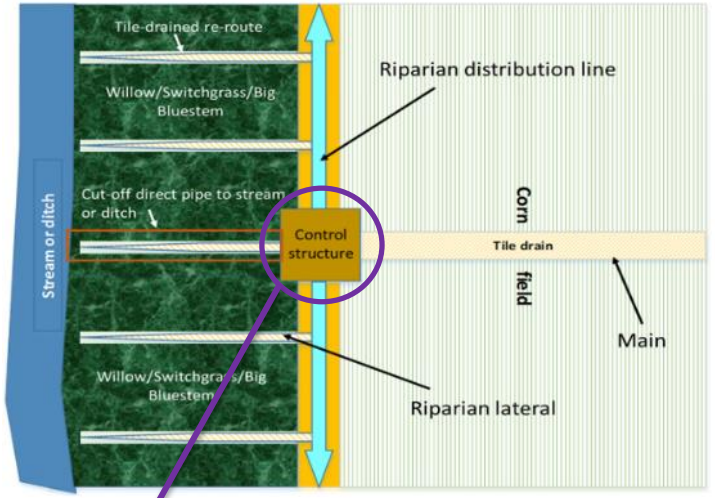
- Crop production (NCCPI)
- Ponding, flooding, drainage, surface runoff (SSURGO)
- Susceptibility of aquifer to nitrate and pesticide leaching (USGS spatial data)



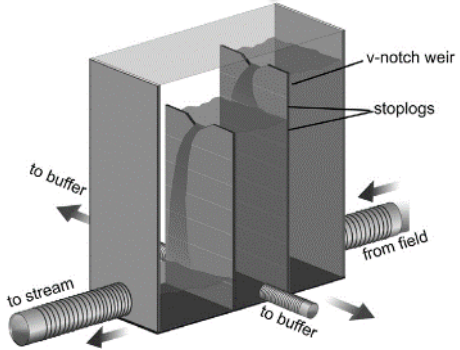
SUPERBEEST's 12-state domain showing overlapping marginality factors

SUITABLE SATURATED BIOENERGY BUFFER (SBB) SITE CLASSIFICATION

- Drain tiles represent a significant source of nitrate flux to surface water
- Capturing nutrient-rich, drainage water via a flow control structure and utilizing it for growing bioenergy crops can improve farm economics in heavily tile-drained systems, while protecting the environment
- We have completed a site suitability model for determining locations favorable for an SBB



Cacho et al. (2021)

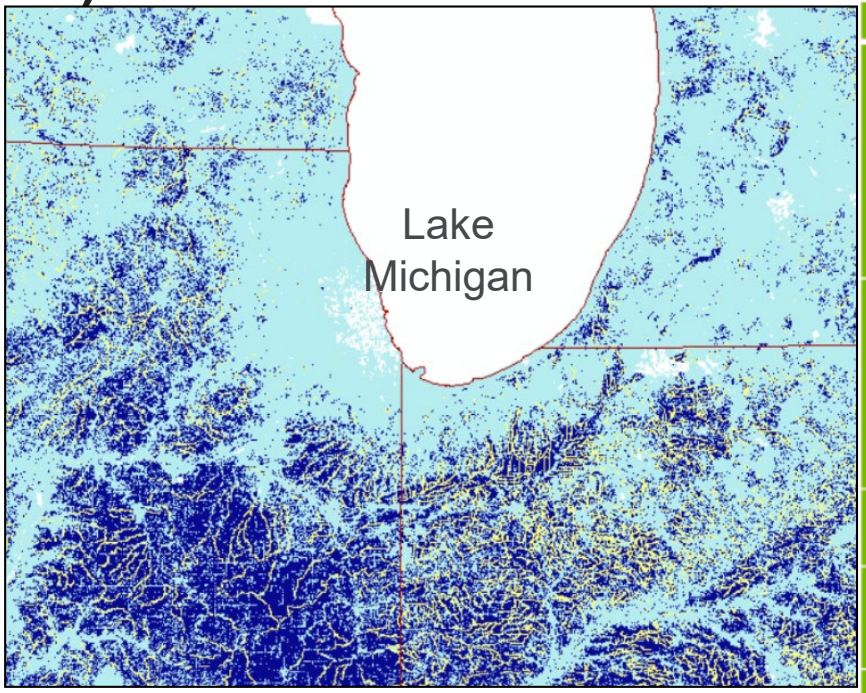


Credit: Jaynes and Isenhart (2014)

- Flow control structure for diverting/recirculating drainage water

SBBS (CONT.)

- For riparian land with width of 20-30 m from ditch/stream edge
- Inputs of soil, topography/slope, LULC, and drainageway locations
- GIS-based multicriteria decision analysis



Example results:
- Dark blue: likely tile-drained
- Yellow: candidate for SBB

Environmental Metric	Classification	Suitability
1. Soil drainage	Somewhat poorly drained	1
	Poorly drained	1
	Very poorly drained	1
	Moderately well drained	0
	Well drained	0
	Somewhat excessively drained	0
	Missing data	Null
2. Topography	Very flat (≤1% slope)	1
	Flat (>1% to ≤2% slope)	1
	Moderately flat (>2% to ≤3% slope)	1
	Slightly flat (>3% to <5% slope)	1
	Not flat (≥5% slope)	0
	Missing data	Null
3. Land use land cover	Corn/soybean	1
	Others	0
	Missing data	Null
4. SOC content in the top 76 cm	Low (<1%)	0
	Medium (1-2%)	1
	High (>2%)	1
	Missing data	Null
5. Depth to hydraulically restricting layer	1.2 - 2.5 m	1
	Otherwise	0
	Missing data	Null
6. Soil erodibility factor (whole soil profile)	Low (≤0.44)	1
	High (>0.44)	0
	Missing data	Null

Cacho, J.F, Quinn, J.J., Zumpf, C.R., and M.C. Negri, 2021, Saturated Bioenergy Buffers: site suitability classification and estimated areas of candidate sites in the U.S. Midwest under three scenarios: Argonne Technical Report ANL/EVS-21/2.

ACTIVITIES IN REMAINING 2 YEARS

- Continue development of SUPERBEEST
  - Determine ecosystem services and estimate their valuation
  - Testing and soliciting feedback
- Refine remote sensing technology for determining economic marginality in irrigated regions where NCCPI information is not applicable
- Perform demand analysis focused on water quality
- Obtain long-term data from Fairbury observatory

SUMMARY

The developing geospatial tool, together with the supporting analyses, aims to fill a gap by providing a decision-making tool for various stakeholders

- Agencies
- Producers (farmer)
- Regulators
- Biorefinery planner
- Trading markets

Our intent is to develop a useful tool to promote adoption of Bio-restore biomass for fueling the Bioeconomy, in support of the BETO Multiplan Plan milestone 19AS22.

Our approach minimizes land use change by focusing on marginal land, focuses on both the environmental benefits and the socioeconomic aspects of perennial bioenergy crops.

Our progress in the first year includes completing the marginality component of SUPERBEEST and overcoming a Go/No-Go evaluation.

Algorithms developed for suitable SBB site classification provide the theoretical basis for inclusion into the SUPERBEEST, enhancing the robustness of the tool's capability for targeting tile-drained riparian areas as sustainable biomass production sites.

Estimated areas from SSB site suitability analysis can inform TEA, LCA, and meta-analyses targeting riparian areas as sustainable biomass production sites in the 12 Midwest states.

Observatory study provides empirical data on subsoil carbon sequestration and plant and soil microbial biodiversity.

QUAD CHART OVERVIEW

Timeline

- Began December 2019
- Ending September 2022

	FY20	Active Project
DOE Funding	(10/01/2019 – 9/30/2020)	$650K per FY ($1,950K total)

Project Partners

- N/A

Barriers addressed

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

Project Goal

The goal is to assist stakeholders in developing biomass sustainably and economically from perennial bioenergy crops (PBC) in marginal agricultural land (MAL) to reduce the cost of biofuel and other bioproducts. Our goal has multifaceted components. We will develop a geospatial tool to 1) identify marginal land in 12 Midwest states at any scale, 2) determine the ecosystem services (ES) that are possible if the MAL were converted to PBC, and 3) estimate the net economic value of the combined production of biomass and ES. In addition, we will explore remote sensing technology for determining economic marginality in irrigated regions where SSURGO information is not applicable, perform a demand analysis focused on water quality improvements and potential trading schemes with water treatment facilities, and continue research on long-term yields and carbon sequestration at our Illinois willow observatory.

End of Project Milestone

Complete and debut the scaled-up geospatial tool through webinars and conference presentations. Present to NRCS the case for inclusion as a tool for assessing and approving conservation practices.

Funding Mechanism

FY20 AOP Lab Call

Q&A DISCUSSION

ADDITIONAL SLIDES

RESPONSES TO PREVIOUS REVIEWERS' COMMENTS

- In 2019, our prior project was peer-reviewed. A key comment from a reviewer dealt with nitrate loss reduction from our field site, and whether this information could be applied elsewhere.
  - This is a driver behind our current Scaling Up project, in order to allow – at any scale – the estimation not only of nutrient loss reduction, but also other potential ecosystem services, and their economic value, while targeting the landscape's marginal land.

PUBLICATIONS COMPLETED SINCE 2019 OR IN PROGRESS

- Zumpf, C., J. Cacho, N. Grasse, J. Quinn, J. Marcel-Hamilton, A. Armstrong, P. Campbell, M.C. Negri, and D.K. Lee, *accepted*, Influence of Shrub Willow Buffers Strategically Integrated in an Illinois Corn-Soybean Field on Soil Health and Microbial Community Composition: Soil Biology and Biochemistry Science of the Total Environment.
- 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.
- Cacho, J.F, Quinn, J.J., Zumpf, C.R., and M.C. Negri, 2021, Saturated Bioenergy Buffers: site suitability classification and estimated areas of candidate sites in the U.S. Midwest under three scenarios: Argonne Technical Report ANL/EVS-21/2.
- U.S. DOE, 2020, Integrated Strategies to Enable Lower-Cost Biofuels: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Bioenergy Technologies Office, DOE/EE-2079. https://www.energy.gov/sites/prod/files/2020/07/f76/beto-integrated-strategies-to-enable-low-cost-biofuels-july-2020.pdf
- Englund, O., I. Dimitriou, V.H. Dale, K.L. Kline, B. Mola-Yudego, F. Murphy, B. English, J. McGrath, G. Busch, M.C. Negri, M. Brown, K. Goss, S. Jackson, E.S. Parish, J. Cacho, C. Zumpf, J. Quinn, and S.K. Mishra, 2020, Multifunctional perennial production systems for bioenergy: performance and progress: WIREs Energy and Environment, https://doi.org/10.1002/wene.375
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- Kreig, J.A.F., H. Ssegane, I. Chaubey, M.C. Negri, and H.I. Jager, 2019, Designing Bioenergy Landscapes to Protect Water Quality: Biomass and Bioenergy: Biomass and Bioenergy. https://doi.org/10.1016/j.biombioe.2019.105327
- Mishra, S.K., M.C. Negri, J. Kozak, J. Cacho, J. Quinn, S. Secchi, and H. Ssegane, 2019, Valuation of Ecosystem Services in Alternative Bioenergy Landscape Scenarios: Global Change Biology Bioenergy,11:748–762. https://doi.org/10.1111/gcbb.12602
- 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, 2019, Positive water linkages of producing short rotation poplars and willows for bioenergy and phytotechnologies: WIREs Energy and Environment, e245, 20 pp. https://doi.org/10.1002/wene.345

PRESENTATIONS SINCE 2019

- Zumpf, C., J. Cacho, J. Quinn, M.C. Negri, C. Lin, and D.K. Lee, 2020, Water Use Estimates of Bioenergy Switchgrass Cropping Systems in the U.S. Midwest, 2020 International Annual Meeting of the American Society of Agronomy, the Crop Science Society of America, and the Canadian Society of Agronomy, virtual, November 9-13.
- Cacho, J., C. Negri, J., Quinn, C. Zumpf, and P. Campbell, 2020, Ecosystem services in alternative bioenergy landscape scenarios: Science and Technology for Development Forum 2020, Caraga State University, Butuan City, Philippines, November 6 (virtual, invited).
- Negri, M.C., John Quinn, Jules Cacho, Colleen Zumpf, Patty Campbell, Nora Grasse, Margaret MacDonell, and Minh Vo, 2020, Bioenergy, Bioproducts and Ecosystem Services: American Institute of Chemical Engineers, 2nd Annual Bioenergy Sustainability Conference (virtual), October 13-15.
- Negri, C., J. Quinn, J. Cacho, C. Zumpf, S.K. Mishra, 2020, The multiple values of bioenergy crops in the Midwest: Renewable Energy Technologies on the Horizon, National Association of Regulatory Utility Commissioners Webinar, August 20.
- Zumpf, C, J. Quinn, J. Cacho, N. Grasse, M.C. Negri, P. Campbell, and D.K. Lee, 2020, Can Shrub Willow Buffers Help Support Biodiversity?: International Association for Landscape Ecology 2020 IALE-North America Annual Meeting, Virtual Remote Conference, Toronto, May 11-14.
- Negri, C., J. Quinn, J. Cacho, C. Zumpf, S.K. Mishra, and P. Campbell, 2020, More than Biomass: Purposefully Grown for Ecosystem Services: Commercial Aviation Alternative Fuels Initiative (CAAFI) webinar, January 16.
- Zumpf, C., N. Grasse, J.T. Hampton-Marcell, P. Campbell, M.C. Negri, J. Quinn, J. Cacho, and D.K. Lee, 2019, Linking Energy and Ecosystem Services: Willow Buffers in an Agricultural Landscape: Illinois Nutrient Loss Reduction Strategy (NLRS) Third Annual Workshop, Springfield, IL, December 3-4.
- Zumpf, C., N. Grasse, J.T. Hampton-Marcell, P. Campbell, M.C. Negri, J. Quinn, J. Cacho, and D.K. Lee, 2019, Linking Energy and Ecosystem Services: Willow Buffers in an Agricultural Landscape: ASA, CSSA and SSSA International Meeting, November 10-13, San Antonio, TX.
- Cacho, J.F., M.C. Negri, J.J. Quinn, M. Ha, L.J. Walston, and M. Wu, 2019, Projected Water Quality Benefits of an Intensively Managed Agricultural Watershed Under an Alternative Bioenergy Landscape: ASA, CSSA and SSSA International Meeting, November 10-13, San Antonio, TX.
- Quinn, J.J., 2019, Phytoremediation: Using Plants to Solve Groundwater and Soil Contamination Challenges: DOE Annual Site Environmental Report/Environmental Monitoring Workshop, Argonne National Laboratory, Argonne, IL, Oct. 22-24.

PRESENTATIONS SINCE 2019 (CONT.)

- Negri, M.C., J. Quinn, J. Cacho, C. Zumpf, P. Campbell, S.K. Mishra, U. Mishra, S. Gautam, and N. Grasse, 2019, Assessment and Valorization of Ecosystem Services through Field Research and Scale Up: Bio-Restore workshop, September 25-26 at Argonne National Laboratory.
- Zumpf, C., J.T. Hampton-Marcell, M.C. Negri, J. Quinn, P. Campbell, J. Cacho, and D.K. Lee, 2019, Linking Energy and Biodiversity: Willow Buffers in an Agricultural Landscapes: Switchgrass V International Conference, Champaign, IL, July 22-25.
- Quinn, J., 2019, Phytoremediation: Using Plants to Solve Groundwater and Soil Contamination Challenges: Olivet Nazarene University seminar, April 29.
- Zumpf, C., J.T. Hampton-Marcell, M.C. Negri, J. Quinn, P. Campbell, J. Cacho, and D.K. Lee, 2019, Linking Energy and Biodiversity: Willow Buffers in an Agricultural Landscape: International Association for Landscape Ecology IALE Annual Meeting, Fort Collins, CO, April 7-11.

WORKSHOP HOSTED SINCE 2019

- DOE BETO Bio-Restore Workshop, September 25-26, 2019 at Argonne National Laboratory.

MEDIA COMPLETED SINCE 2019

- Bioenergy and Ecosystem Services, a website serving as a living, electronic poster of research group efforts. https://web.evs.anl.gov/bioenergy/
- “Argonne scientists transform farming with biomass buffers” an Argonne website feature story, by Jo Napolitano, June 17, 2019. https://www.anl.gov/article/argonne-scientists-transform-farming-with-biomass-buffers https://www.youtube.com/watch?v=1scEgMnF0-8
- “Promoting sustainable bioenergy landscapes through the quantification of ecosystem services” a Research Highlight of the Environmental Science Division, Argonne National Laboratory, March 26, 2019. http://www.evs.anl.gov/news/2019/03-26-bioenergy-landscapes.cfm

MULTIYEAR PLAN (MYP) AND BARRIERS

This Scaling Up project focuses on BETO's MYP milestone of:

- 19AS22 Verify landscape-design approaches for at least one bioenergy system that, when compared to the conventional agricultural and logistics systems, will increase practical agricultural biomass supply availability by 100% or more on a per acre basis, while maintaining or enhancing ecosystem services.

…while addressing the following barriers:

- At-B Analytical Tools and Capabilities for System-Level Analysis
- At-E Quantification of Economic, Environmental, and Other Benefits and Costs
- At-F Science-Based Methods for Improving Sustainability