OAK RIDGE National Laboratory

DOE Bioenergy Technologies Office (BETO) 2021 Project Peer Review

Quantifying & Visualizing Progress Toward Sustainability

WBS# 4.2.2.40

March 11, 2021 @ 11:35 am EST

Session: Data, Modeling, and Analysis

PI: Dr. Esther Parish

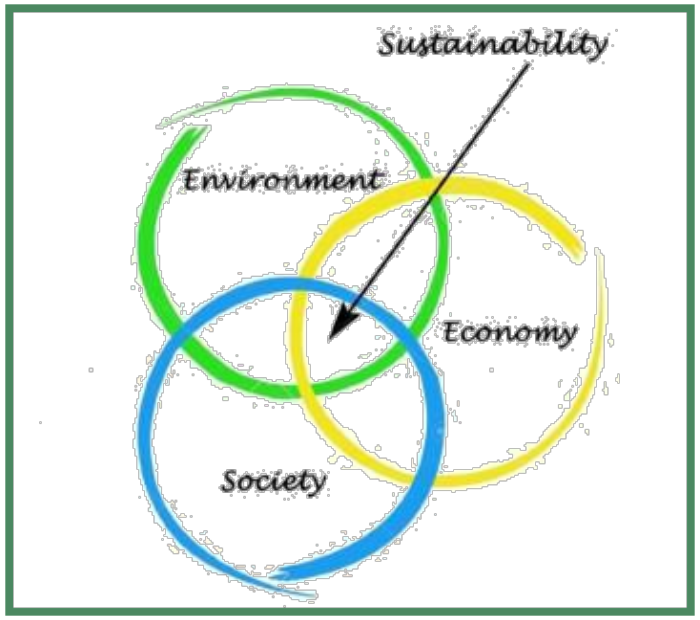
Recipient: ORNL

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

Project Overview

- Year 3/3 of project designed to quantify landscape-scale environmental and socioeconomic benefits and costs of bioenergy projects using an indicator-based sustainability assessment approach
- Our research helps build the US knowledge base to inform future decision-making regarding cellulosic bioenergy feedstock choices and management practices suited to local contexts (i.e., geographic setting & stakeholder priorities)
- We are building a web-based visualization tool, **BioSTAR,** that can be used to compare and evaluate sustainability synergies and trade-offs of bioenergy production in real-world situations

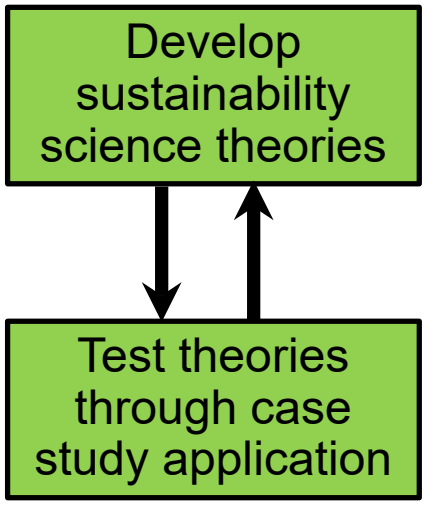


BioSTAR = Bioenergy Sustainability Tradeoffs Assessment Resource

Management: Project Structure

Funding is divided evenly between two intertwined tasks:

Task 1: Fundamental research related to the quantification and visualization of key environmental and socioeconomic indicators and their interactions across various spatial scales (e.g., fuelsheds, watersheds, subfields). We test and refine our sustainability assessment approach through case studies conducted with project collaborators, including the USDA Forest Service, industries, universities, other DOE labs, and IEA Bioenergy researchers



Task 2: Develop an online decision support tool (BioSTAR) to ensure that lessons learned under Task 1 are shared with a broad range of bioenergy stakeholders & that stakeholders are provided with an opportunity to expand the knowledge base. Since Dec 2019, we have been refining BioSTAR's interface through bi-monthly consultation with 3 industry and university partners

Management: Interdisciplinary ORNL Project Team

Esther Parish
Geographer and landscape ecologist; uses GIS and integrated models to study environmental and socioeconomic sustainability of renewable energy resources

Principal Investigator
(Tasks 1 & 2)

Keith Kline
> 30 years of international experience with sustainable development projects involving renewable energy systems and community engagement

Stakeholder Engagement
(Tasks 1 & 2)

Forest Carter
Full stack web and GIS developer; trained cartographer specializing in natural resource management

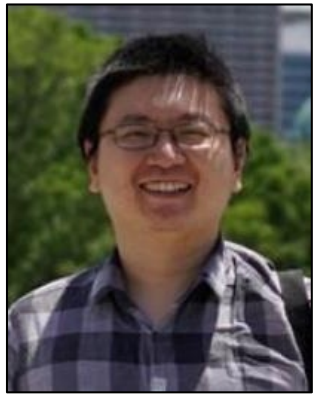
BioSTAR Developer
(Task 2)

Mike Hilliard
Specializes in mathematical analysis, visualization, simulation, and optimization techniques; created Billion-Ton 2016 data visualizations

Data Visualization
(Tasks 1 & 2)

Rebecca Efroymson
Risk assessment expert with 30 years experience studying environmental effects of energy technologies

Indicator & Target Development
(Tasks 1 & 2)



Fie Xie
Researcher specializing in optimization of biofuel supply chains, analytics, and decision sciences

Indicator Optimization
(Task 1)

Management: Case Study Collaborations

East Tennessee switchgrass

Photo by P. McDaniels, University of Tennessee Institute of Agriculture.

SE US wood pellets

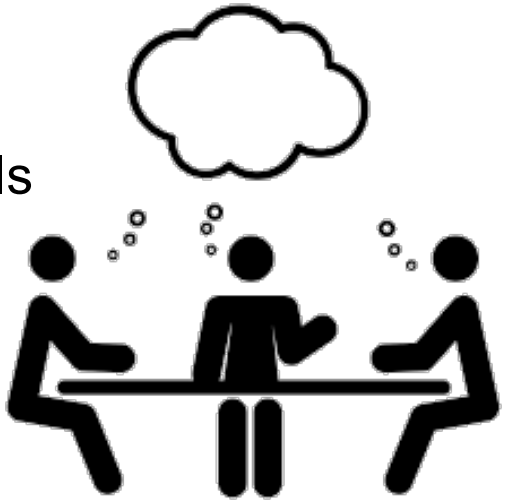
Photo from DominicanToday.com

Iowa stover & switchgrass

Photo by Esther Parish

Management: Routes of Collaboration & Communication

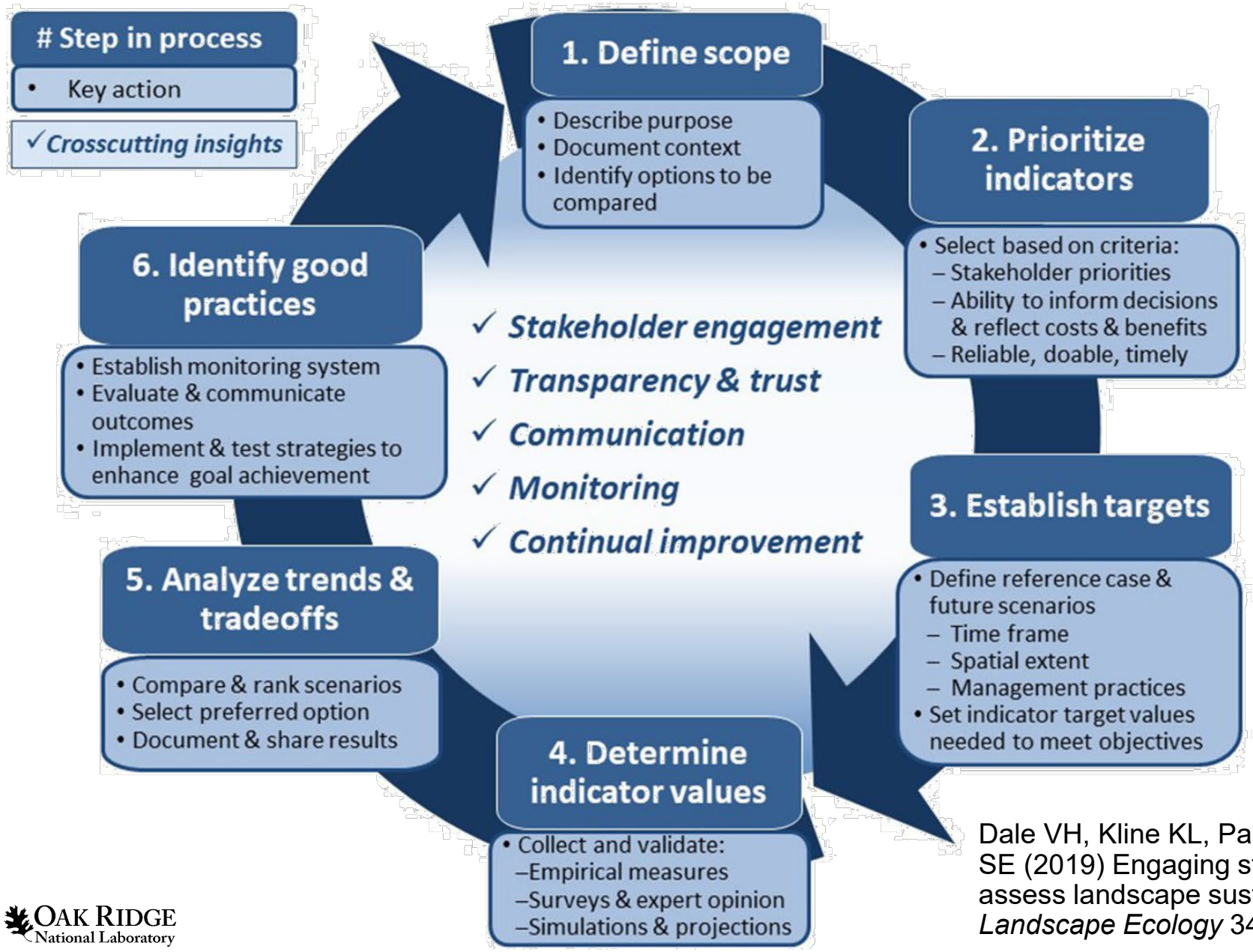
- Joint publications in peer-reviewed journals
- Joint conference presentations
- BioSTAR feedback collected from beta test at May 2019 IEA Bioenergy Workshop in Athens, GA
- Weekly check-ins with ORNL's Bioresource & Engineering Group
- Bi-weekly discussions with BETO's multi-lab Sustainable Land Management Working Group (SLMWG) to discuss
  - Integration of bottom-up and top-down modeling of bioenergy costs & benefits
  - Development of US case study to inform IEA Bioenergy Task 45, "Sustainability effects of bioenergy within the broader bioeconomy"
- Monthly Antares-led webinars with the Iowa Landscape Design team
- Monthly BETO reports & webinars for "Data, Modeling & Analysis" project PIs
- Bi-monthly webinars with BioSTAR's industry & university partners
- Quarterly reports & check-ins with BETO Technical Monitor
- Annual in-person meetings with the Iowa Landscape Design team



Management: Project Risks & Mitigation Strategies

Risk	Description	Mitigation Strategy
Insufficient data	Potential risk of not getting enough indicator datasets of sufficient quantity & quality for consistent visualization of progress toward sustainability for all 12 environmental & socioeconomic categories	Narrow focus to a few key indicators that have the best available data
Lack of active participation by collaborators	Potential risk that one or more of our collaborators will decide that BioSTAR is not worth their voluntary investment of time and energy	Narrow focus to the case study (or case studies) of the collaborators who remain interested in developing BioSTAR for future use

Approach: Background/History



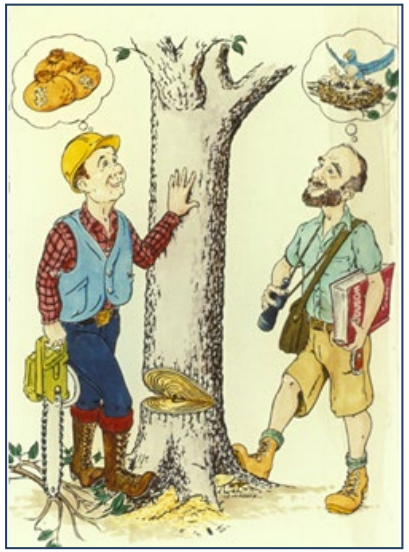
- Project builds from FY16-18 BETO project "Bioenergy Sustainability: How to Define and Measure It" (PI: V Dale)
- Recently published approach synthesizes decades of research & field experiences to help others implement a process for quantifying progress toward sustainability
- Approach is refined through case studies at landscape scales (e.g., fuelsheds)

Dale VH, Kline KL, Parish ES, Eichler SE (2019) Engaging stakeholders to assess landscape sustainability. *Landscape Ecology* 34(6):1199–1218.

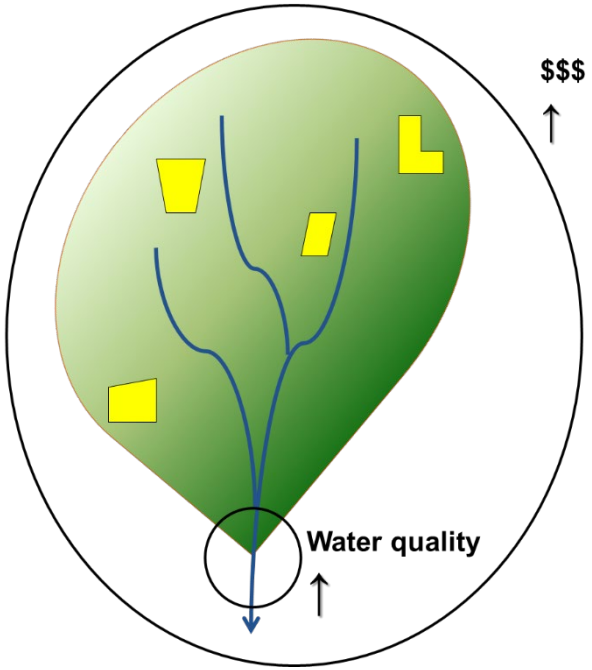
Approach: Advance Sustainability Science

How should we set targets for the selected environmental & socioeconomic indicators?

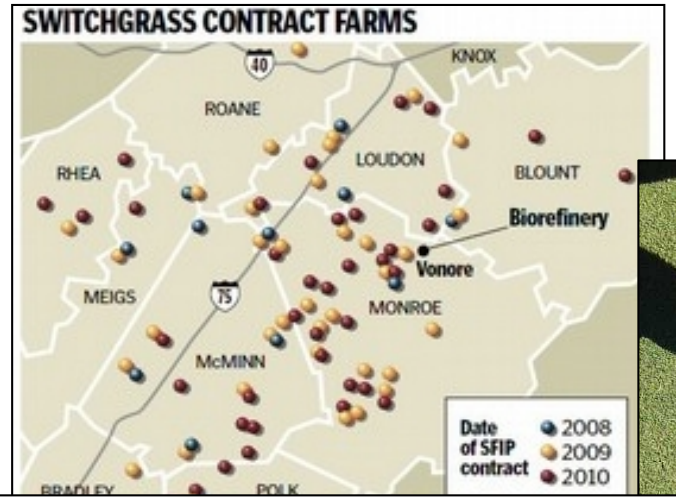
How will local prioritization of indicators by stakeholders affect sustainability outcomes?

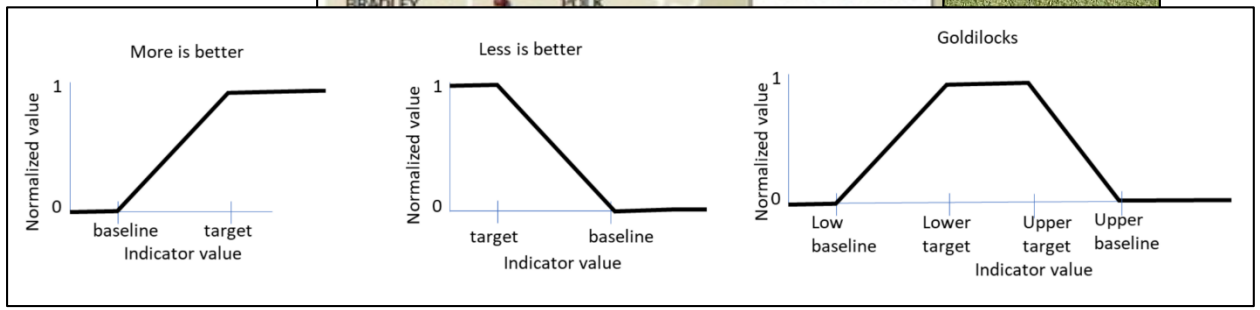


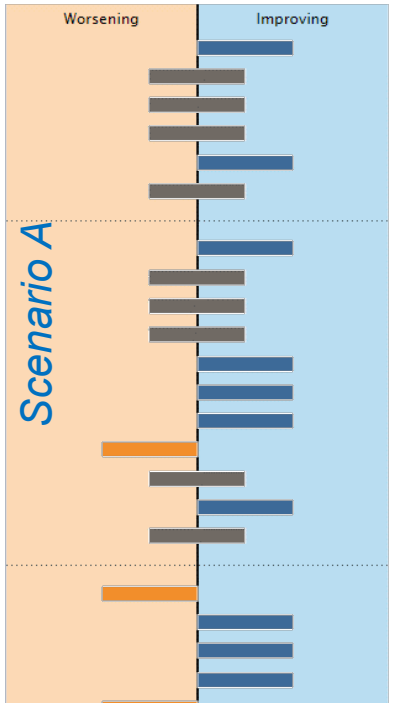
How can combinations of indicators be used to maximize benefits from landscape design alternatives?

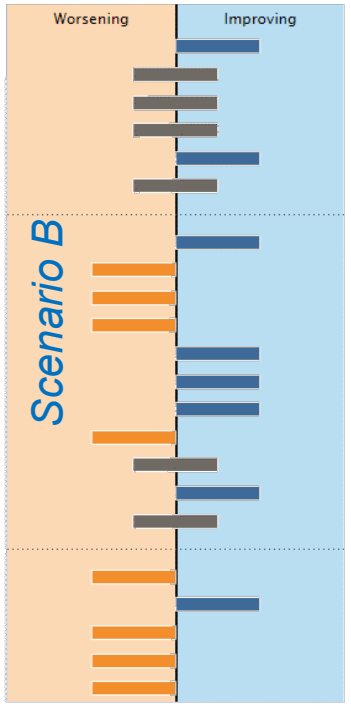


How can we integrate and visualize indicator data collected across many spatial and temporal scales?









What are the most effective ways to visualize and compare changes to a set of indicators across different scenarios?

Approach: Make BETO's Research Accessible to Stakeholders

- BioSTAR is designed to guide users through the 6-step sustainability assessment process by:
  - ✓ selecting key environmental & socioeconomic indicators
  - ✓ setting baseline & target values
  - ✓ mapping & visualizing progress across scenarios
- BioSTAR shares data & results from ORNL's case studies
- Industry & university partners have been testing BioSTAR's interface with their own projects

We plan to release BioSTAR on https://bioenergykdf.net by September 2021

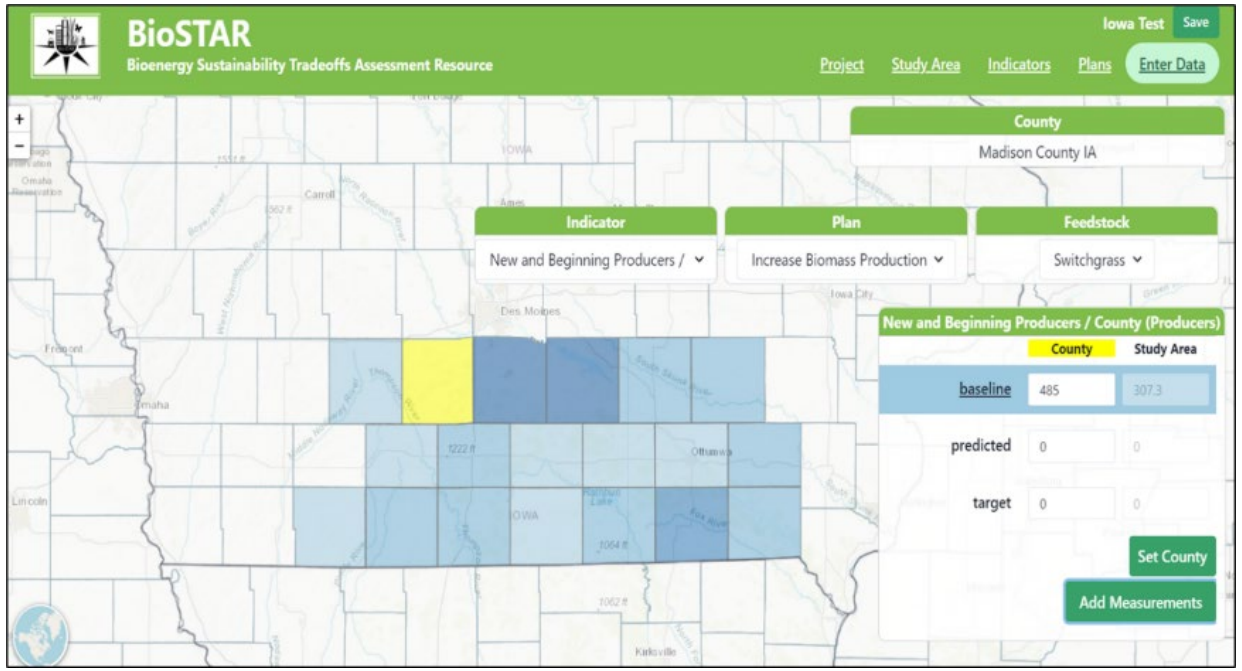
Approach: Project Go/No Go Decision Point for BioSTAR tool

Verified that BioSTAR can accept & display indicator datasets contributed by non-ORNL users

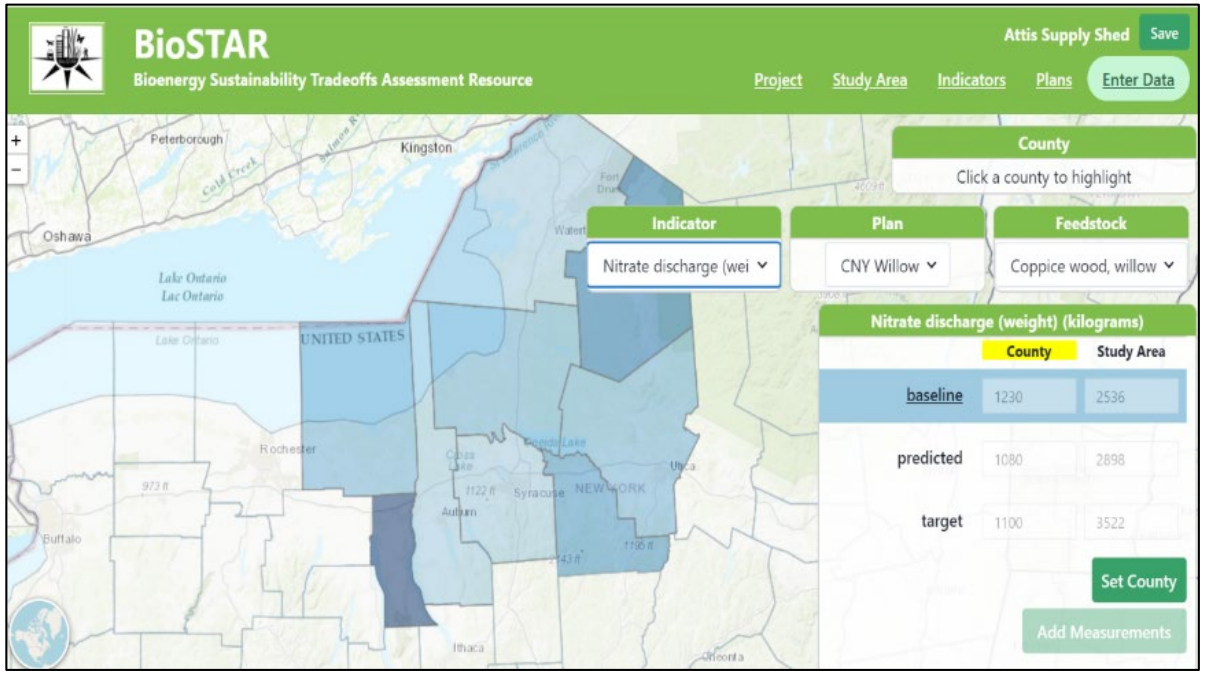
June 2020 Go/No Go Milestone

Demonstrate two separate examples:
1. User uploads indicator dataset
2. Data gets processed
3. Indicator results are visualized graphically

Success resulted in a "Go" decision to continue developing BioSTAR



Demonstration 1: Noah Etka (Antares) defined 19-county fuelshed in southern Iowa and entered 11 indicator datasets



Demonstration 2: Ted Koch (SUNY ESF) defined 9-county fuelshed in upstate NY and entered 6 indicator datasets

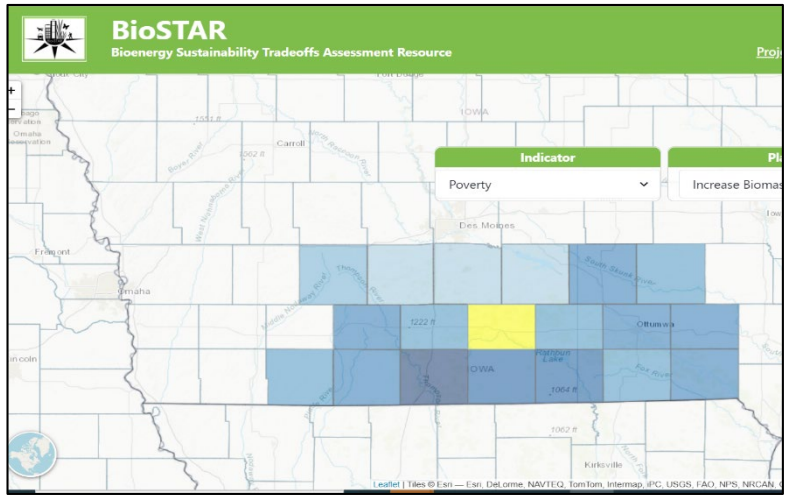
Approach: Top Challenges

1. **Reconciling priorities of our 3 industry & university partners in addition to BETO as we prepare BioSTAR for public release**

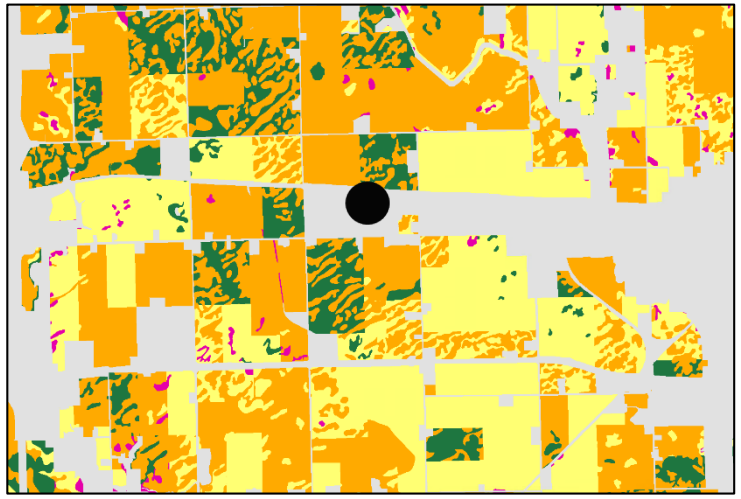
Example:

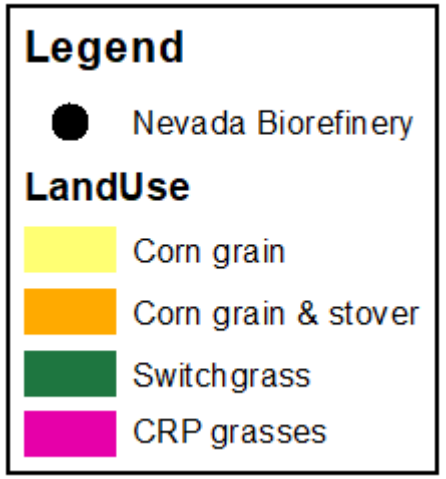
Invest time in visualizing differences between management scenarios?
OR
Invest time in finding & incorporating more baseline indicator datasets?

2. **Integrating social & economic datasets with more highly resolved environmental datasets can lead to mismatches between indicator categories. Relative lack of established methods for downscaling socioeconomic data complicates case study analyses of synergies & tradeoffs**



VS.





County-scale poverty data

Subfield-scale crop data

Impact: Overcoming Bioeconomy Barriers

Project is addressing two needs identified in BETO's Multi-Year Program Plan:

- **Science-Based Methods for Improving Sustainability**
- **Quantification of Economic, Environmental, and Other Benefits & Costs**

We are building a web-based visualization tool, BioSTAR, that can be used to compare and evaluate sustainability costs & benefits of cellulosic bioenergy production in real-world situations

MAXIMIZE BENEFITS

- ✓ Rural Jobs
- ✓ Farmer Profits
- ✓ Soil Quality
- ✓ Water Quality
- ✓ Biodiversity
- ✓ Reduced Carbon Emissions
- ✓ Energy Security

Impact: Stakeholders are Interested in BioSTAR

- Since Jan 2020, 3 industry & university partners have been actively engaged in BioSTAR's development
- They test BioSTAR's evolving interface & provide feedback to help us meet project milestones:
  - ☑ Demonstrate that users can upload & visualize datasets *(June 2020)*
  - ❑ Incorporate indicator aggregation methodology into BioSTAR *(June 2021)*
  - ❑ Release functional BioSTAR tool on Bioenergy KDF *(Sep 2021)*

Partner	End Uses for BioSTAR
ESF College of Environmental Science and Forestry, State University of New York, 1911	• Facilitate discussions with State of New York re: greenhouse gas reduction goals • Education tool for students • Develop renewable power for Fort Drum Army Base & Honeywell International using willow
UTIA Institute of Agriculture, The University of Tennessee	• Develop & promote sustainable jet fuel supply chain for the Nashville & Memphis airports using an oilseed cover crop (*pennycress*)
Antares Group Incorporated	• Help farmers attain Sustainability Certification

"BioSTAR is very innovative, and if successful, could yield strong rewards to local and regional decision makers and planners."—*2018 Project Merit Reviewer*

Progress & Outcomes: Developed Analysis Framework to Minimize Land Management Impacts on Species of Concern

Tested analysis framework with *Gopherus polyphemus*, a keystone species in SE USA where bioenergy wood pellets are produced

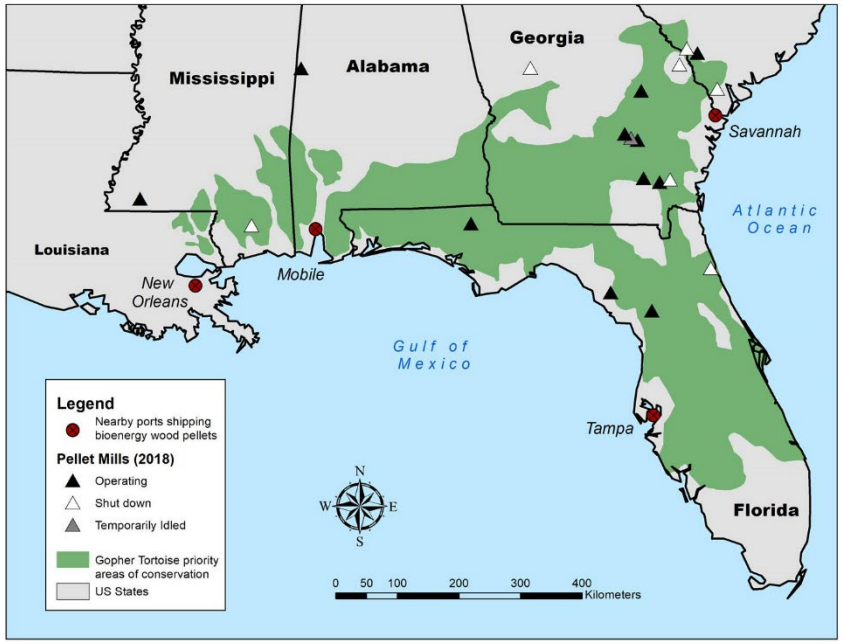
1. Select species of concern because they are rare or have cultural, commercial, or recreational importance

2. Determine life-history conditions at risk for species of concern

3. Determine management practices that can affect those life-history conditions

4. Assess potential effects of each management practice on each life-history condition

5. Identify practices that can avert or mitigate negative impacts



Figures from *World Biomass 2020/2021* article by Dale, Baskaran & Parish based on Parish et al. (2020)

Identified practices that can minimize wood pellet production impacts on gopher tortoise, including forest thinning and keeping vehicles >4 m away from burrows

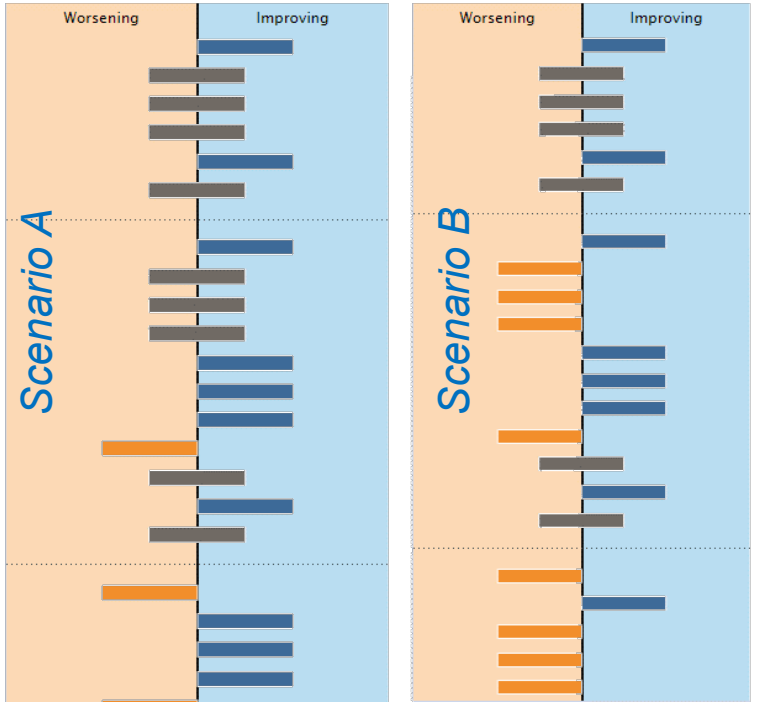
Progress & Outcomes:
Successful BioSTAR Demonstration at International Workshop

IEA Bioenergy
Technology Collaboration Programme

Warnell School of Forestry & Natural Resources
UNIVERSITY OF GEORGIA

Bio-STAR

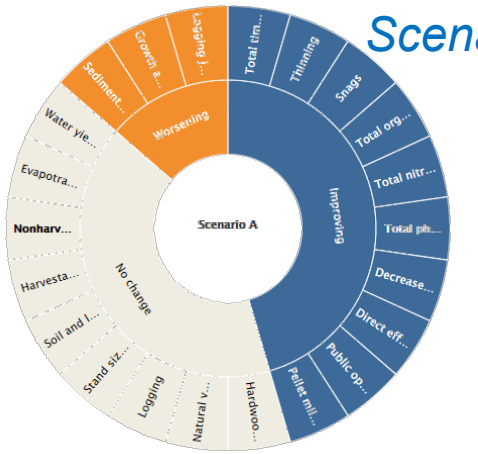
- Developed & shared BioSTAR prototype with foresters, researchers & industry representatives at **May 2019 wood pellet workshop** hosted by IEA Bioenergy and UGA's Warnell School of Forestry and Natural Resources
- Usability surveys + additional feedback collected from **32 session participants**
- Prepared "Report on the utility & ease of use of the BioSTAR prototype tool"

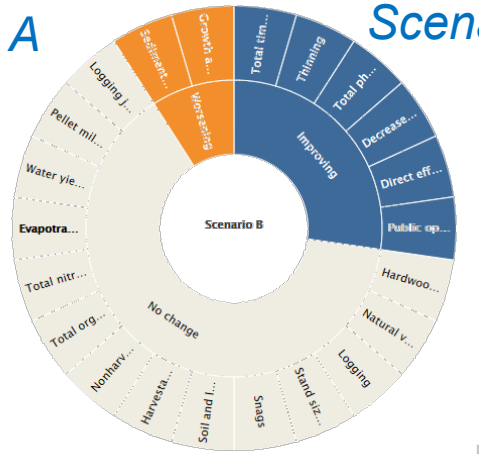


Example feedback requested:

Which visualization do you prefer for comparing changes to a set of indicators across scenarios?

Trellis *(left)* or **Starburst *(below)***?

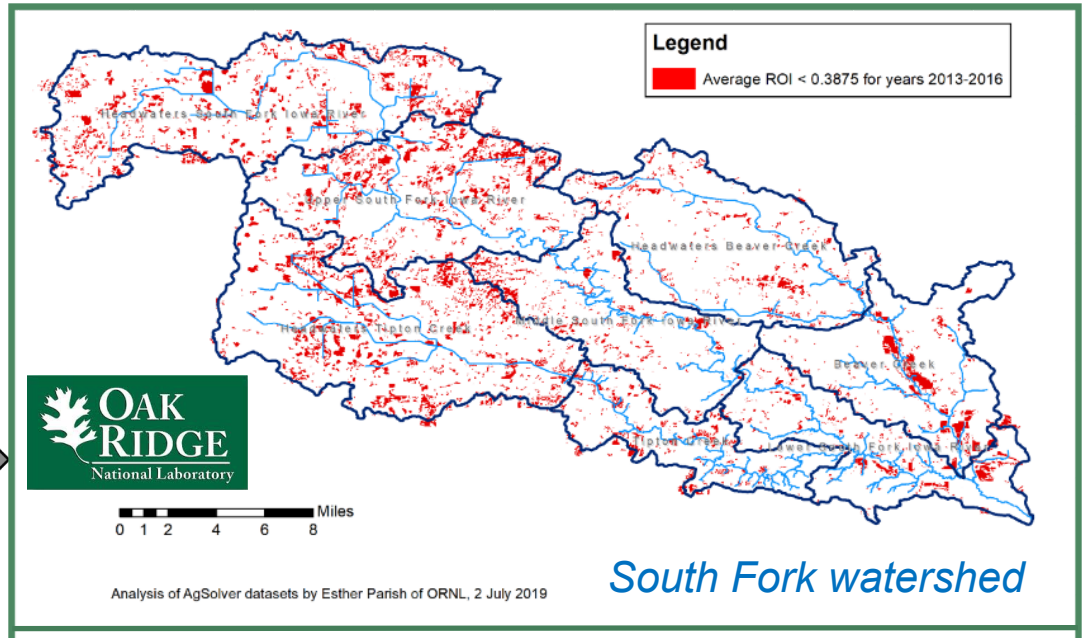




Progress & Outcomes: Successful Collaboration for Landscape Design

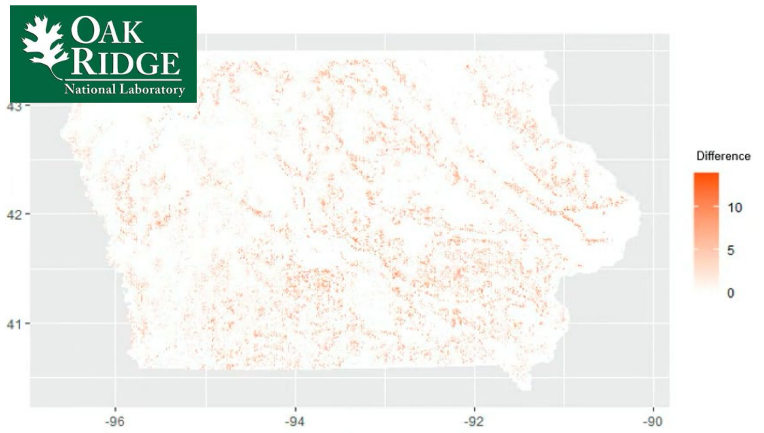
ANTARES Group Incorporated · EFC·SYSTEMS

AgSolver & Profit Zone Manager (PZM) datasets for all of Iowa at subfield scale



South Fork watershed

We developed GIS layers of clustered, low-profit corn/soy subfields targeted for switchgrass at scales of 2 watersheds, 2 fuelsheds & Iowa



BioEST modeling by Kreig & Jager shows **8% increase in Iowa's species richness** with targeted switchgrass plantings

Argonne NATIONAL LABORATORY

Ha & Wu incorporated layers into **SWAT** model to assess potential water quality improvements in 2 watersheds, leading to joint publication by Ha et al. (2020)

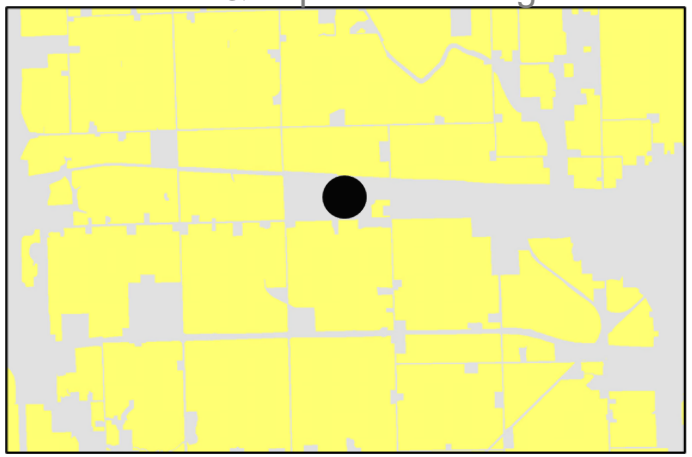
PennState

Rozum & Kemanian incorporated layers into **Cycles** model to assess agroecosystem impacts of landscape design on productivity & environmental performance at field & watershed scales

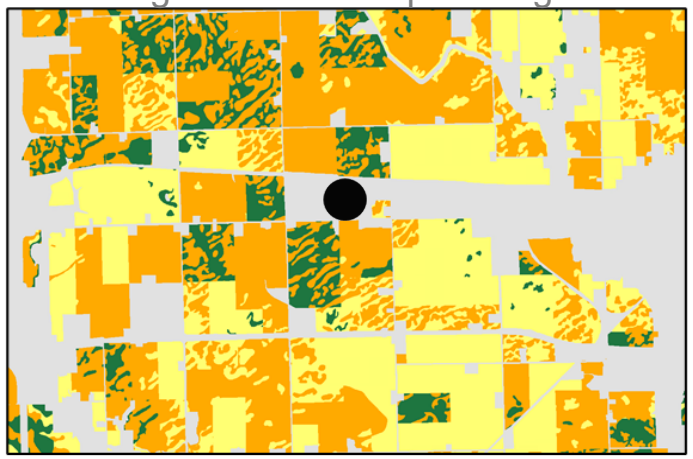
Progress & Outcomes: Iowa Landscape Design Scenario Development

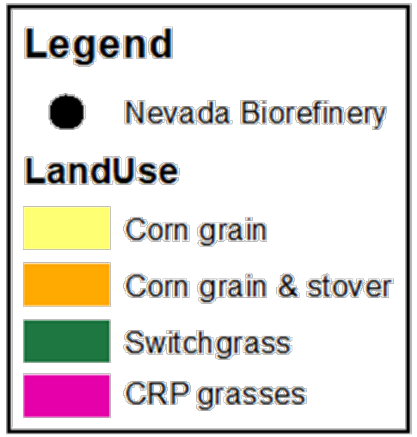
Worked with BETO Projects 4.2.2.63 (PI: Comer) & 3.1.4.001 (PI: Kline) to define 4 alternative scenarios and develop corresponding geospatial layers for quantification of sustainability indicators

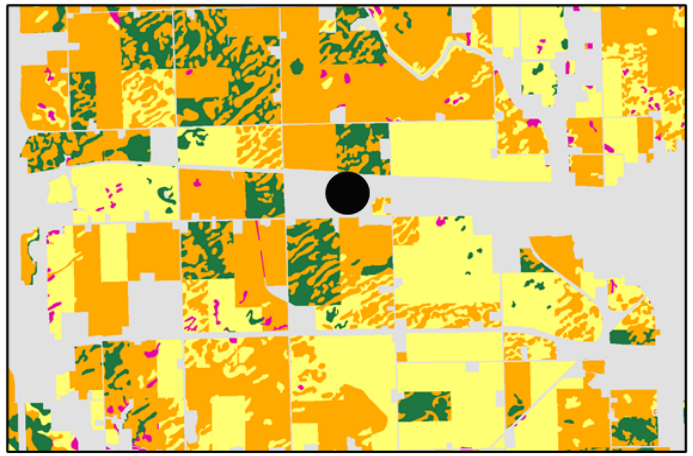
Basecase & Improved Management

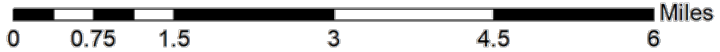


Integrated Landscape Design A





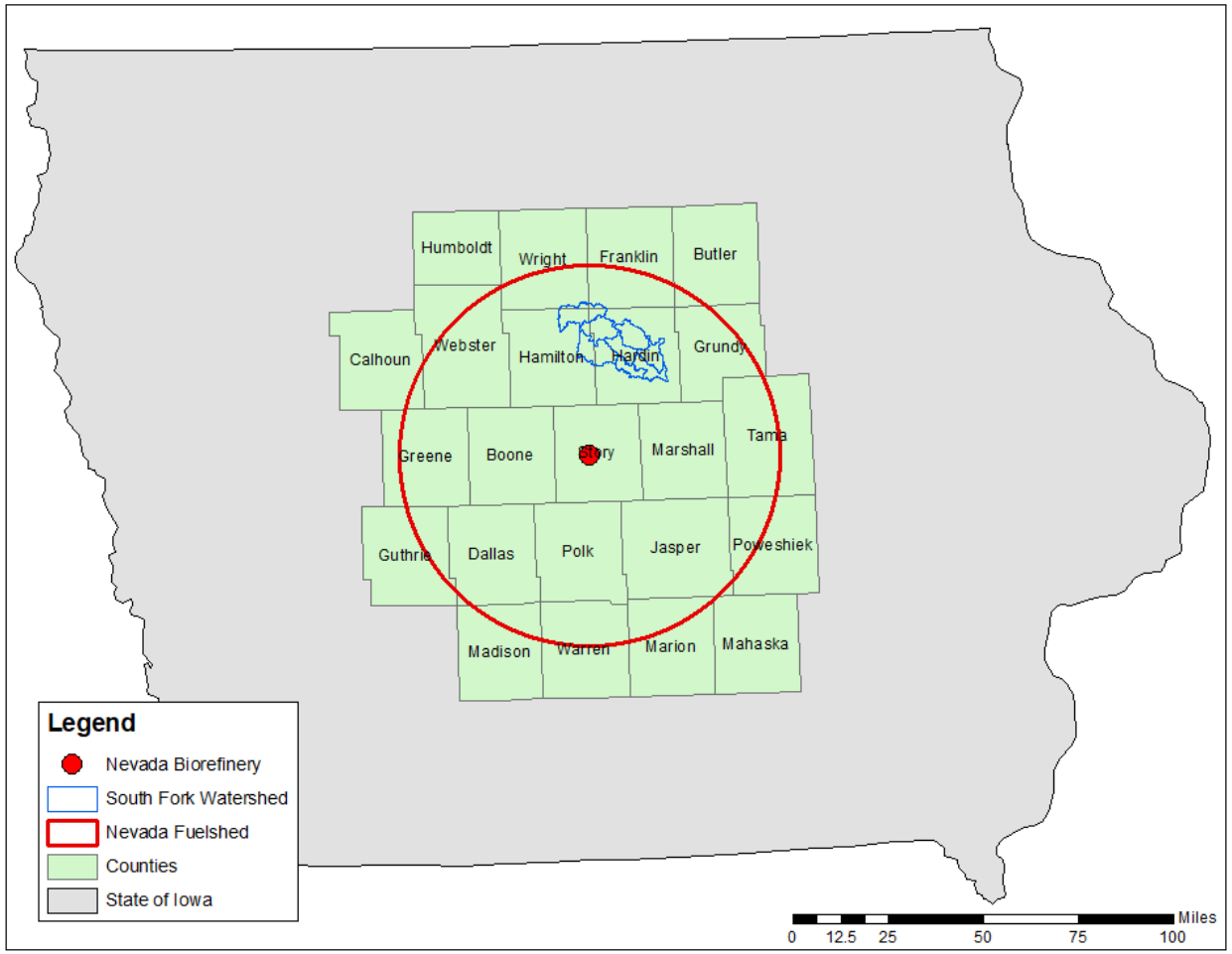


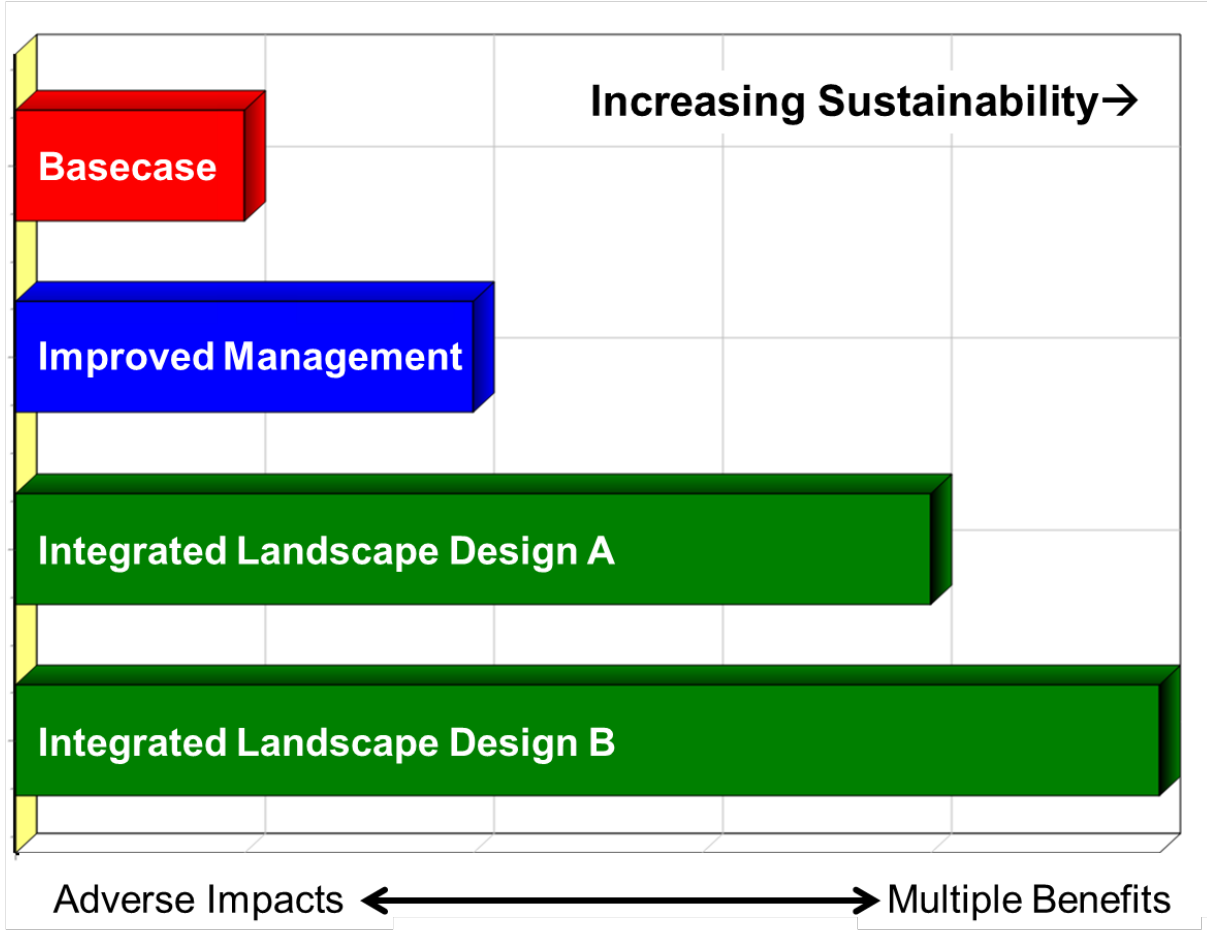


Integrated Landscape Design B

1. **Basecase:** corn/soy production on all fields, no conservation practices, no bioenergy
2. **Improved Management Case:** corn/soy production on all fields, some conservation practices, no cellulosic bioenergy market
3. **Integrated Landscape Design A:** bioenergy switchgrass plantings on clusters of unprofitable corn/soy subfields + 30% corn stover removal from suitable locations (with rye cover crop and no till)
4. **Integrated Landscape Design B:** bioenergy switchgrass plantings on clusters of unprofitable subfields + 45% corn stover removal from suitable locations + rye cover crop and no till for all corn/soy acres + CRP plantings on remainder of low ROI subfields

Progress & Outcomes: Iowa Sustainability Case Study Completed

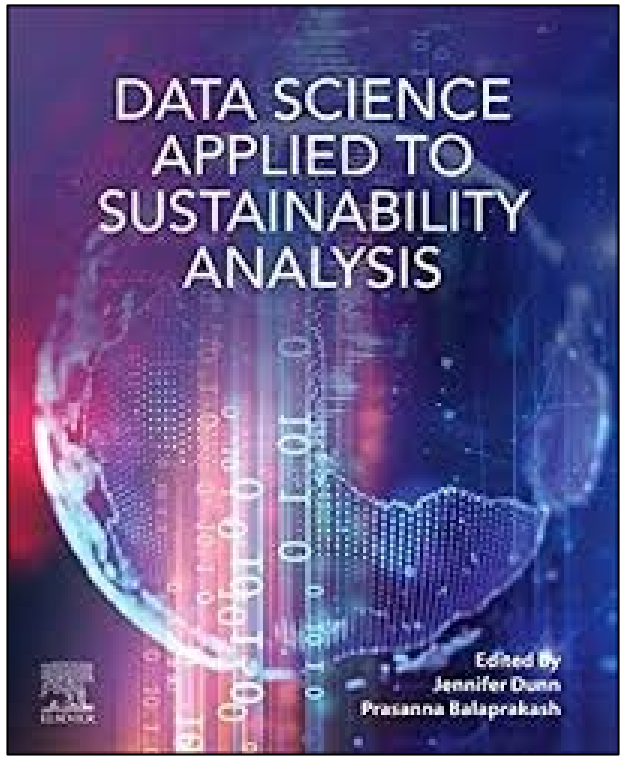




Quantified trends & tradeoffs in Iowa biomass systems at the scale of **Nevada fuelshed** and **South Fork watershed** using data collected by the Antares Iowa Landscape Design Team. ORNL's sustainability model outputs show that **integrated landscape designs can provide multiple benefits at both scales**, including increased biodiversity, improved soil & water quality, reduced soil erosion, and climate change mitigation

Progress & Outcomes:

Invited book chapter for *Data Science Applied to Sustainability Analysis*



Chapter 13

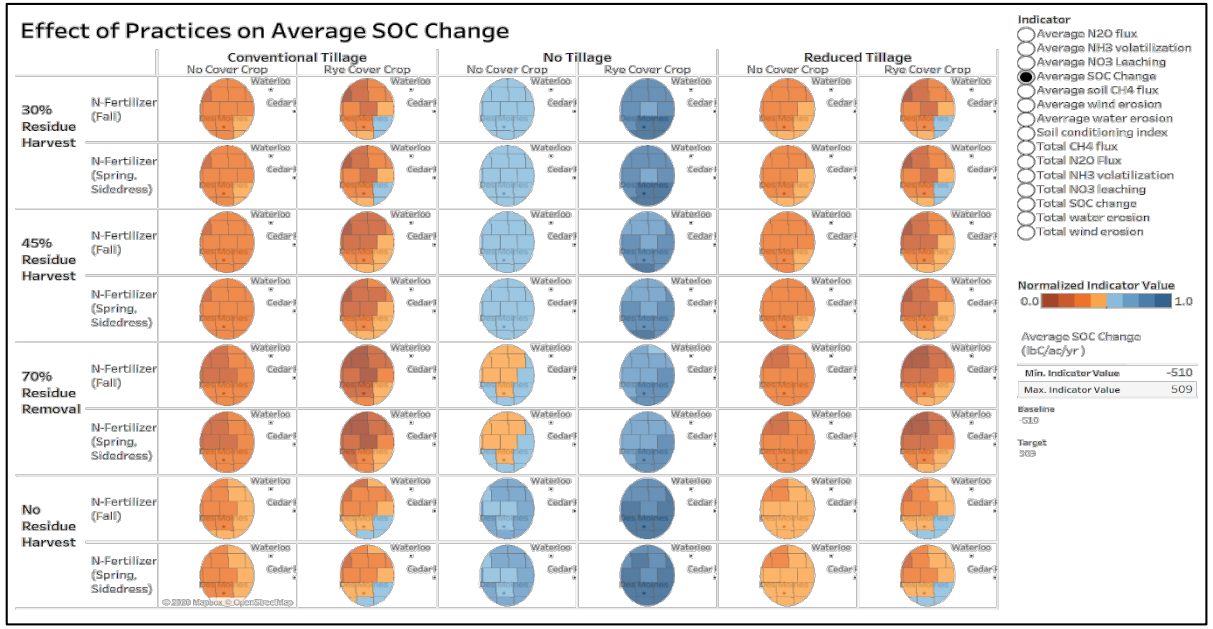
An indicator-based approach to sustainable management of natural resources

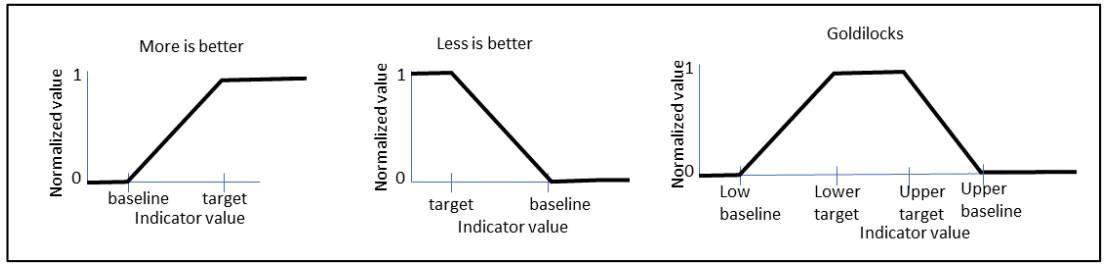
Esther Parish[a,*], Virginia Dale[b], Maggie Davis[a], Rebecca Efroymson[a], Michael Hilliard[a], Henriette Jager[a], Keith Kline[a], Fei Xie[a]

[a]Oak Ridge National Laboratory
[b]University of Tennessee
*Corresponding author.

Release date:
May 1, 2021

Array of maps displaying modeled changes in soil organic carbon (SOC) under 48 alternative management scenarios across 16 Iowa counties





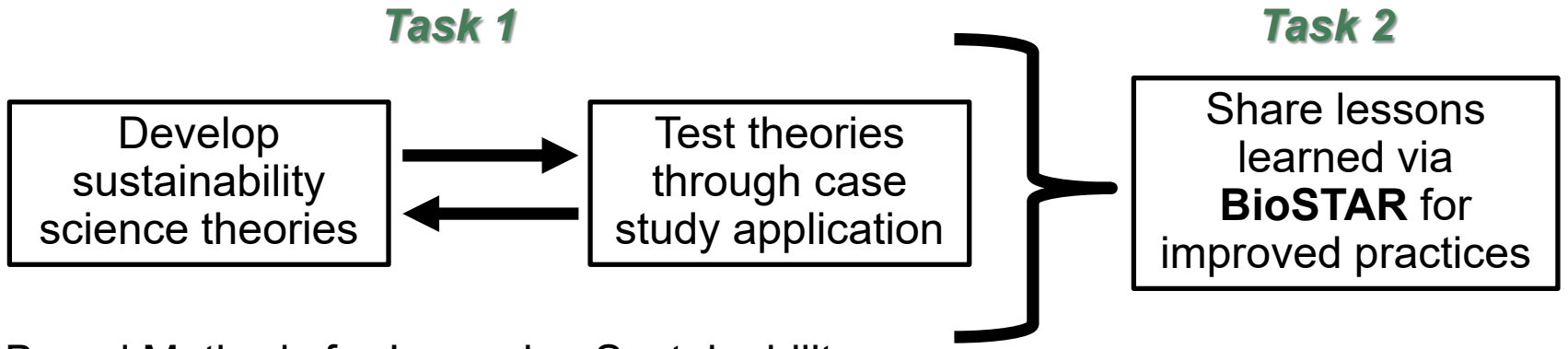
Normalization transformations based on direction of indicator improvement

Summary

Management

Interdisciplinary Team addressing landscape-scale Environmental & Socioeconomic Sustainability of bioenergy production through Case Studies of multiple feedstock types conducted with many Collaborators

Approach

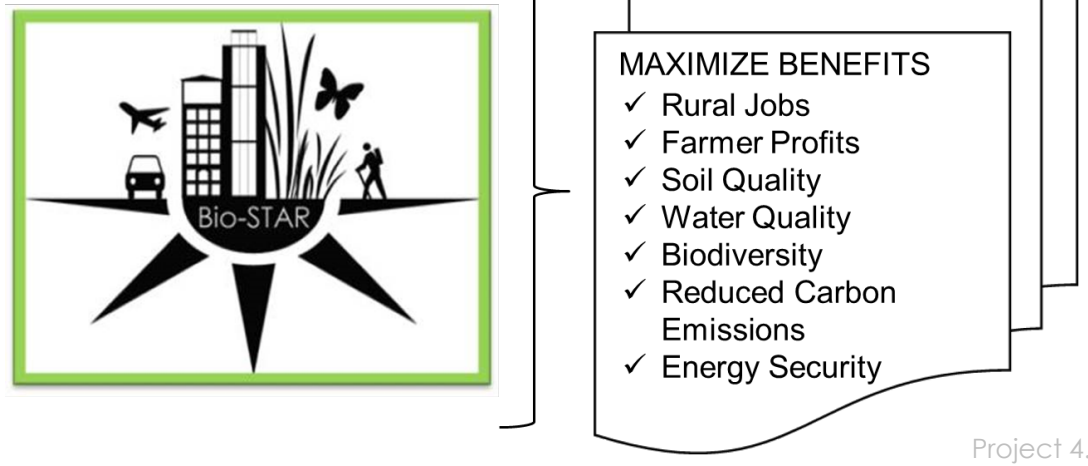


Impact

- Science-Based Methods for Improving Sustainability
- Quantification of Economic, Environmental, and Other Benefits & Costs

Progress & Outcomes

BioSTAR will help DOE & bioenergy stakeholders to compare and evaluate sustainability costs & benefits of cellulosic bioenergy production in real-world situations



Additional Slides for Peer Reviewers

Quad Chart Overview of Project 4.2.2.40

Timeline

- October 1, 2018
- September 20, 2021

	FY20	Active Project
DOE Funding	$650,000	$1,950,000 total for FY19-21

Project Partners

USDA Forest Service & ARS, IEA Bioenergy, UTIA, Antares, EFC Systems, SUNY ESF, ANL, INL, NREL, Penn State, Iowa State, NCSU, UGA, Michigan State, Genera & more

Barriers addressed

- Quantification of Economic, Environmental, and Other Benefits & Costs (At-E)
- Science-Based Methods for Improving Sustainability (At-F)

Project Goal

Design and develop a web-based tool, the Bioenergy Sustainability Tradeoffs Assessment Resource (BioSTAR), to help stakeholders assess the landscape-scale sustainability of their bioenergy projects. Using lessons learned from scientific case studies of cellulosic bioenergy production, BioSTAR will integrate environmental and socioeconomic indicators to quantify and visualize sustainability synergies and trade-offs of bioenergy production in real-world situations. In this way, future benefits can be maximized & negative impacts avoided

End of Project Milestone

Release functional BioSTAR tool on the Bioenergy KDF website

Funding Mechanism

BETO Annual Operating Plan (AOP)

March 2019 Peer Review Comments

- "It is not clear that the model described can be generalized. Can it [BioSTAR] be applied to new cases other than the case studies under consideration?"
- "Knowing there are many existing sustainability certification schemes and approaches for varying audiences, the team should think carefully about and communicate whether and/or how BioSTAR differs from existing certification/sustainability schemes."
- "Thirty-five indicators* are very comprehensive. It would be hard to rigorously assess them in a single case study—let alone build a generalized model capable of doing so for all possible cases."

Adjustments in Project Approach

- For FY20-21, the project has engaged industry and university partners to focus BioSTAR's development. These 3 partners have been testing BioSTAR's user interface with their own project information & advising us on ways to make the tool useful and unique.
- We have narrowed our focus from 35 indicators* to key indicators selected in conjunction with stakeholders. Within BioSTAR, users can now select indicators which are most meaningful & manageable for their projects.

** ORNL's starting checklist of 35 indicators includes 19 environmental (McBride et al. 2011) and 16 socioeconomic indicators (Dale et al 2013) in 12 categories.*

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Recent Presentations & Panels

- Vazhnik V, Parish E, Henrich C, Richard T. “Incorporating the stakeholders into agricultural sustainability assessments.” US-IALE presentation given by Veronika Vazhnik of Penn State/INL on April 10, 2019 in Fort Collins, Colorado.
- Parish ES. “Explore ORNL's recent sustainability case study of two Southeast US wood pellet supply areas using a prototype Bioenergy Sustainability Tradeoffs Assessment Resource (BioSTAR) tool.” A 3.5-hour collaborative session with 32 participants held on May 3rd as part of the May 1-3, 2019 IEA Bioenergy Workshop at the Warnell School of Forestry & Natural Resources, University of Georgia, Athens, GA.
- Keith Kline served as an invited panelist for "Panel Discussion #3: Opportunities for Encouraging Collaboration, Finding Common Ground, and Developing Trust” and co-led an interactive poster session with Virginia Dale (ORNL Corporate Fellow Emeritus) to identify potential risks from woody bioenergy production as part of the May 1-3, 2019 IEA Bioenergy Workshop held at UGA.
- Esther Parish was invited by the US Forest Service to give a “Celebrating Our Successes” presentation at the USDA Southern Research Station/Forest Inventory and Analysis Employee Training and Development held in Oak Ridge, TN on August 13-15, 2019. Esther’s presentation with Consuelo Brandeis (USFS) was entitled “FIA Data in Action: Exploring Wood-Pellet Production Effects.”
- Esther Parish presented “Development of a Bioenergy Sustainability Tradeoffs Assessment Resource (BioSTAR)” at the Bioenergy Sustainability Conference hosted by the American Institute of Chemical Engineers (AIChE) in Nashville, TN on October 21-22, 2019.
- Keith Kline chaired the October 2019 AIChE Bioenergy Sustainability Conference at the request of Gerald Tuskan of the Center for Bioenergy Innovation (CBI) and facilitated collaboration with researchers involved with the DOE Office of Science Bioenergy Research Centers.
- Esther parish presented “Use of FIA datasets to analyze effects of wood-based bioenergy production” at the 2019 FIA Stakeholders Science Meeting held on November 19-21, 2019 in Knoxville, Tennessee. Co-authors included Keith Kline, Consuelo Brandeis and Jeffery Turner of the USDA Forest Service, and Virginia Dale of the University of Tennessee.
- Rebecca Efroymson, Esther Parish and Keith Kline prepared an e-poster entitled, “Setting target values for indicators of sustainable land management” for the AAAS Meeting held in Seattle, WA on Feb 13-16, 2020.
- On May 29, 2020, Esther Parish presented “Bottom-Up Modeling for Sustainable Land Management” at the virtual kickoff for the BETO multi-lab Sustainable Land Management Working Group (SLMWG) organized by NREL.
- Esther Parish was invited to serve on the “Metrics and Indicators” Panel of the virtual Bioeconomy Initiatives Forum on September 15, 2020 along with Jeremy Guest of the University of Illinois and Ralph Hogan of the Roundtable on Sustainable Biomaterials. The panel was moderated by Brian Heninger of EPA and generated good discussion.