DOE Bioenergy Technology Office (BETO)

WBS 4.2.1.20 Integrated Landscape Management

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Data, Modeling & Analysis

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Project Overview

Project Overview (cont'd)

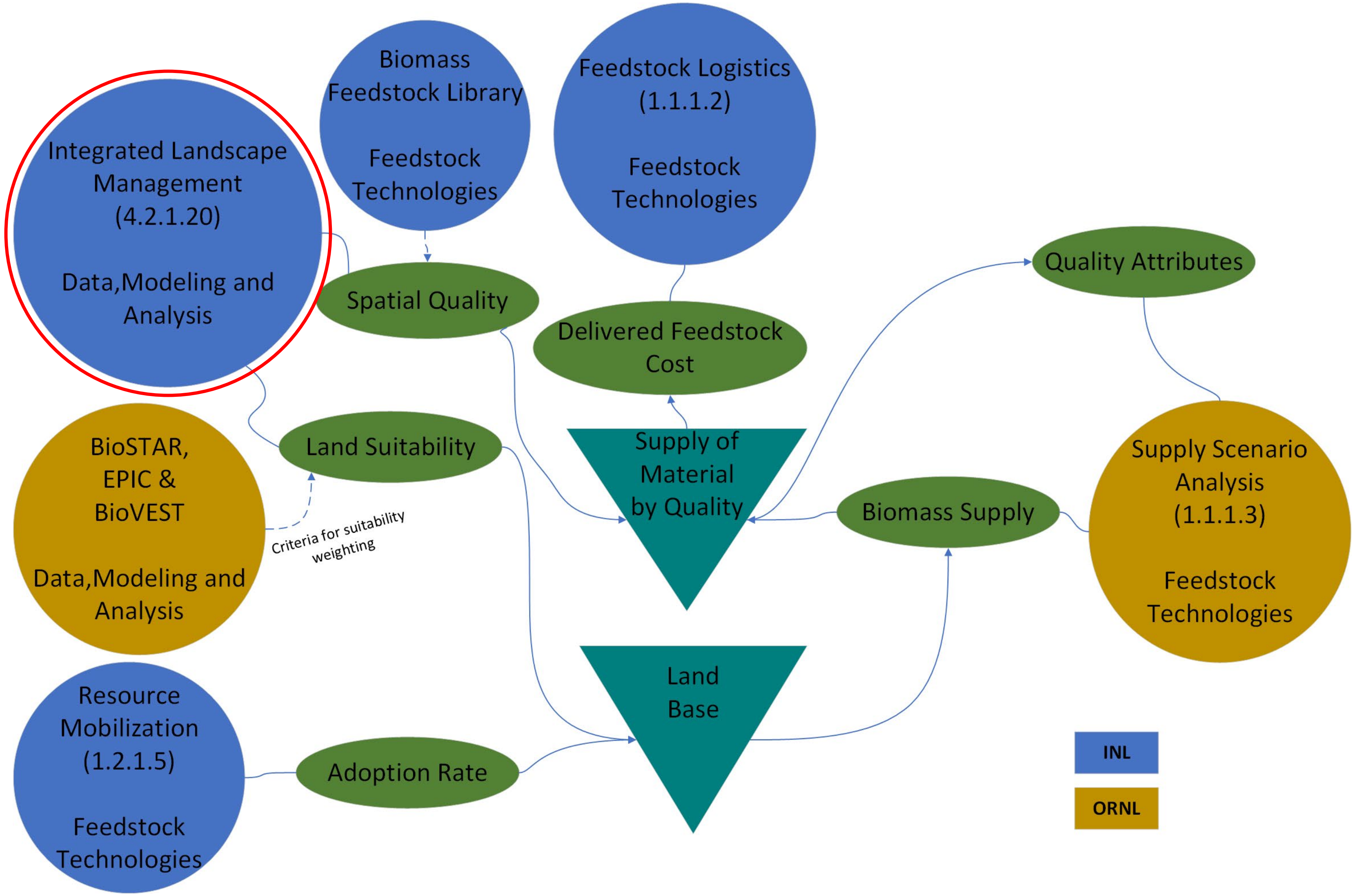
Project Goals

- Develop model pathways to improve sustainability of feedstock supply chains.
  - Reduce access costs by at least 20 percent
  - Reduce environmental footprint (soil organic carbon, reduced erosion)
- Maintain/improve industrial relevance.
- Support the Bioenergy Technology Office (BETO)'s renewable fuel cost target (2030) of $2.50/gge.

Project Overview (cont'd)

What?	How?	Why?	Risks?
Harness synergies of production/collection practices and current systems to improve economic and environmental outcomes.	Opportunities exist in many industries to support an emerging bioeconomy. However, there are many barriers for integration.	It is vital to develop sustainable modelled pathways to engage and guide industry.	Ensuring modelling efforts are industrially relevant. Acquiring relevant data.

Management


Integrated Landscape Management (4.2.1.20)
Data,Modeling and Analysis
Biomass Feedstock Library
Feedstock Technologies
Feedstock Logistics (1.1.1.2)
Feedstock Technologies
Spatial Quality
Delivered Feedstock Cost
Quality Attributes
BioSTAR, EPIC & BioVEST
Data,Modeling and Analysis
Land Suitability
Criteria for suitability weighting
Supply of Material by Quality
Biomass Supply
Supply Scenario Analysis (1.1.1.3)
Feedstock Technologies
Land Base
Resource Mobilization (1.2.1.5)
Feedstock Technologies
Adoption Rate
INL
ORNL

Management (cont’d)

- Participate in the Working Group on Sustainable Land Management.
- Contribute to Feedstock Logistics and Feedstock Production & Management Interagency Working Groups (IWGs).
- Bi-weekly conference calls with ORNL.
- Four milestones per year (SMART).
- Team members
  - Damon Hartley, Yinqian Lin, Danho Ange Lionel Toba, David Thompson
- Project risks
  - Maintaining industrial relevance
  - Data gaps

Management (cont’d)

Project schedule

- Integrated Landscape Management completed a 3-year AOP (FY18 – FY20) on September 30, 2020.
- Modelling efforts were centered around herbaceous feedstock supply systems.
- Efforts supporting the new 3-year AOP (FY21 – FY23) are focused on woody feedstock supply systems.

Approach

Evaluate lessons learned and identify capability gaps from previous analysis efforts to support goals.

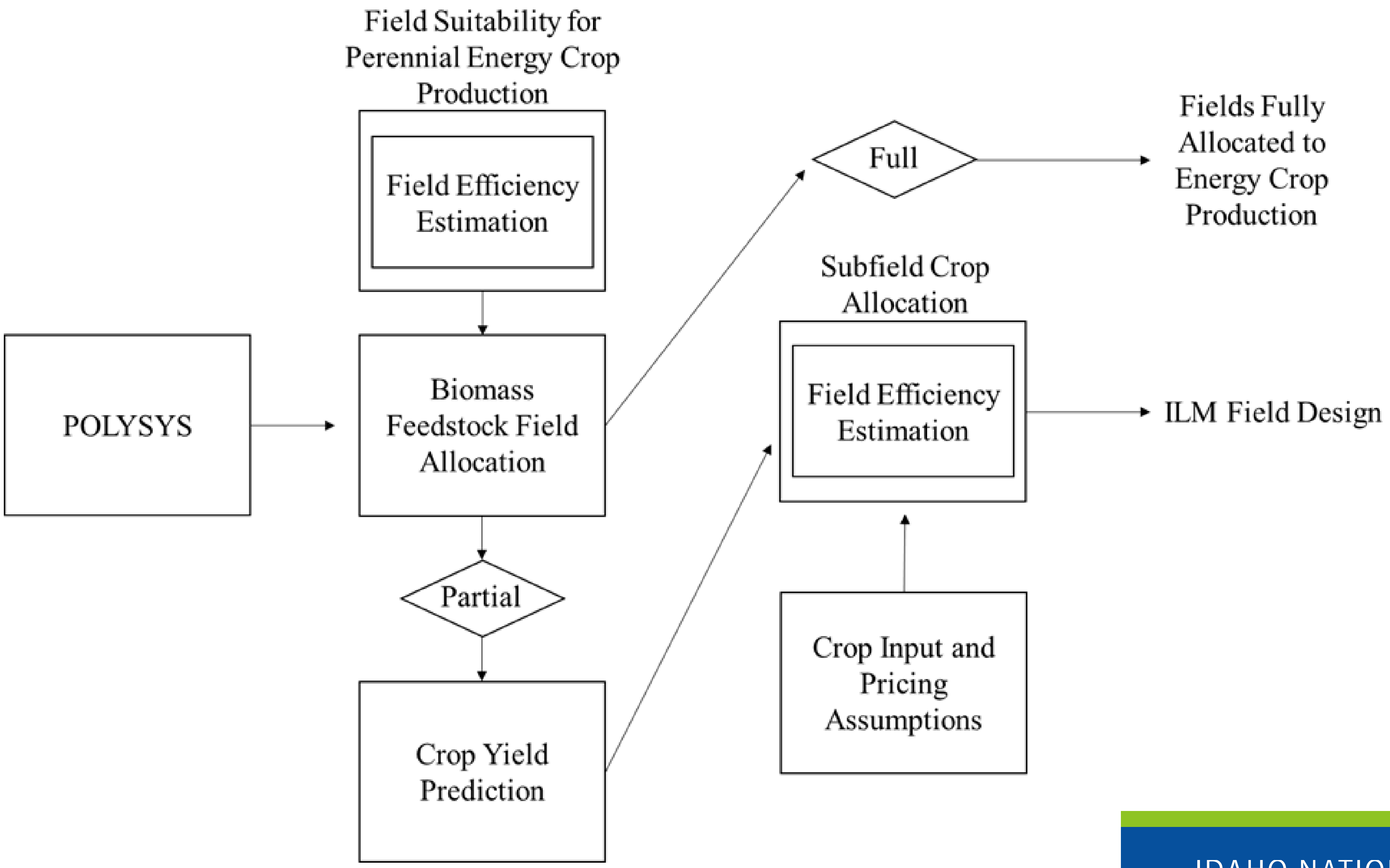
- *Field Efficiency Estimation* – a method to estimate equipment field efficiency based on field shape and area metrics
- *Field Suitability for Perennial Energy Crop Production* – the ability to identify and score agricultural fields most suitable (environmentally and economically) for biomass feedstock production
- *Biomass Feedstock Field Allocation* – a technique to allocate county-level biomass feedstock production estimates derived from the Policy Analysis System Model (POLYSYS) in coordination with researchers at Oak Ridge National Laboratory (ORNL)

Approach (cont'd)

Evaluate lessons learned and identify capability gaps from previous analysis efforts to support goals.

- *Crop Yield Prediction* – the ability to access high spatial resolution row crop yield variability data
  - This was a Go/No-Go decision point in FY19 Q2
- *Subfield Crop Allocation* – a capability that incorporates data/methods from the previously described capabilities along with necessary assumptions to generate optimal agricultural field designs incorporating energy and row crop production that can maximize economic and environmental outcomes based on user priorities

Approach (cont'd)



Approach (cont'd)

A new AOP cycle started in FY21 focused on woody feedstock supply systems.

- Identify suitable woody feedstocks (short-rotation, forest management).
- Incorporate spatiotemporal factors impacting material attributes.
- Develop modelled supply chains capable of balancing economic and environmental concerns while meeting quality targets.

Impact

- This project impacts the state of technology by developing novel and industrially relevant modelling capabilities to support the integration of biomass feedstock production into the existing agricultural ecosystem.
- These tools and methods can be used to support supply chain development for an emerging bioeconomy in ways that mitigate economic and environmental concerns.
- This project has generated or contributed to multiple publications, technical reports, conference presentations, and a patent application.
- Negotiations are ongoing with two industrial partners to utilize project modelling capabilities for agricultural stakeholders.
- R&D 100 Award recipient in 2020 for Crop AIQ.

Progress and Outcomes

Field Efficiency Estimation

- Compiled empirical machinery movement data representative of agricultural field operations.
- Developed modelling and simulation capabilities to measure field operation efficiencies to account for ILM impacts on biomass harvest and logistics costs and grower field operations efficiencies.

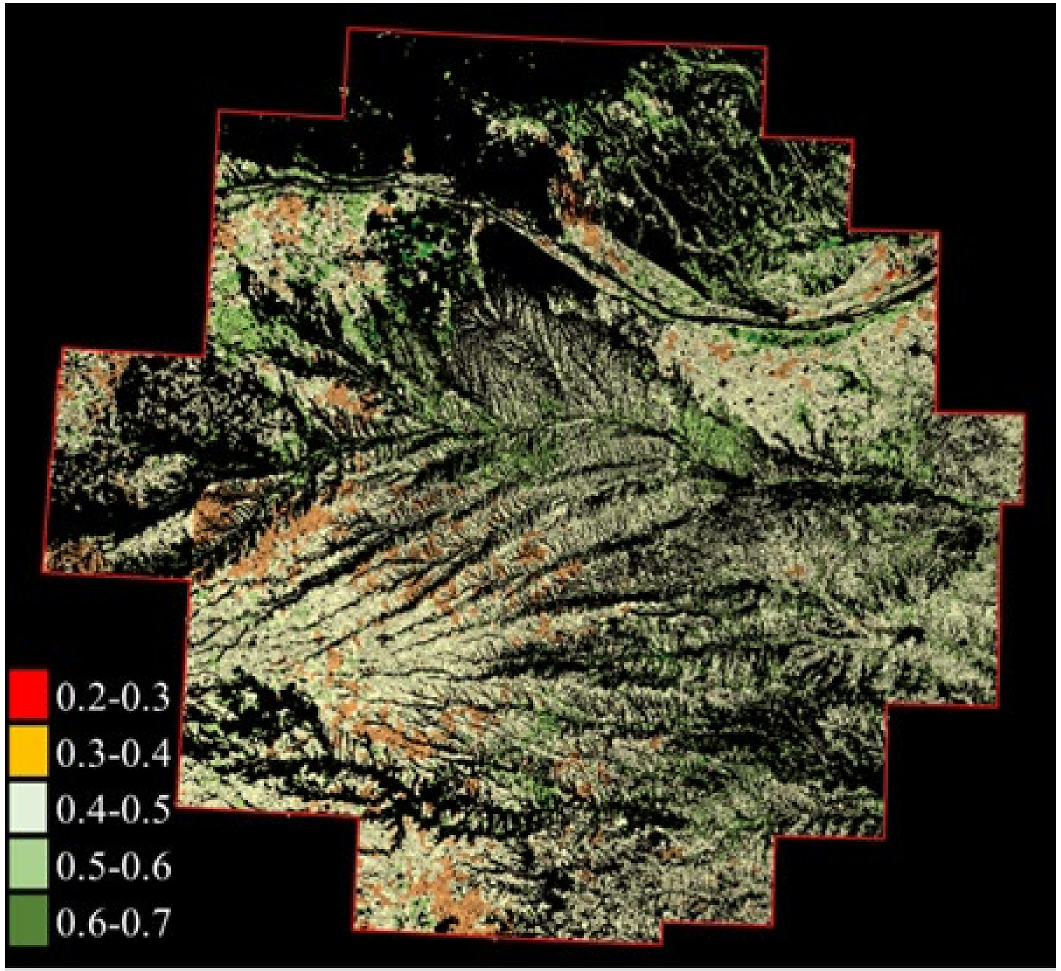
$$Field\ Efficiency = \frac{T_{work}}{T_{work} + T_{breaks}}$$

Progress and Outcomes (cont'd)

Field Suitability for Perennial Energy Crop Production

- Established a site suitability framework to score agricultural fields for suitability for biomass production.
- Criteria span agronomic, field operability, and environmental domains.
- This provides a tool to identify suitable fields at "fuelshed" scales.

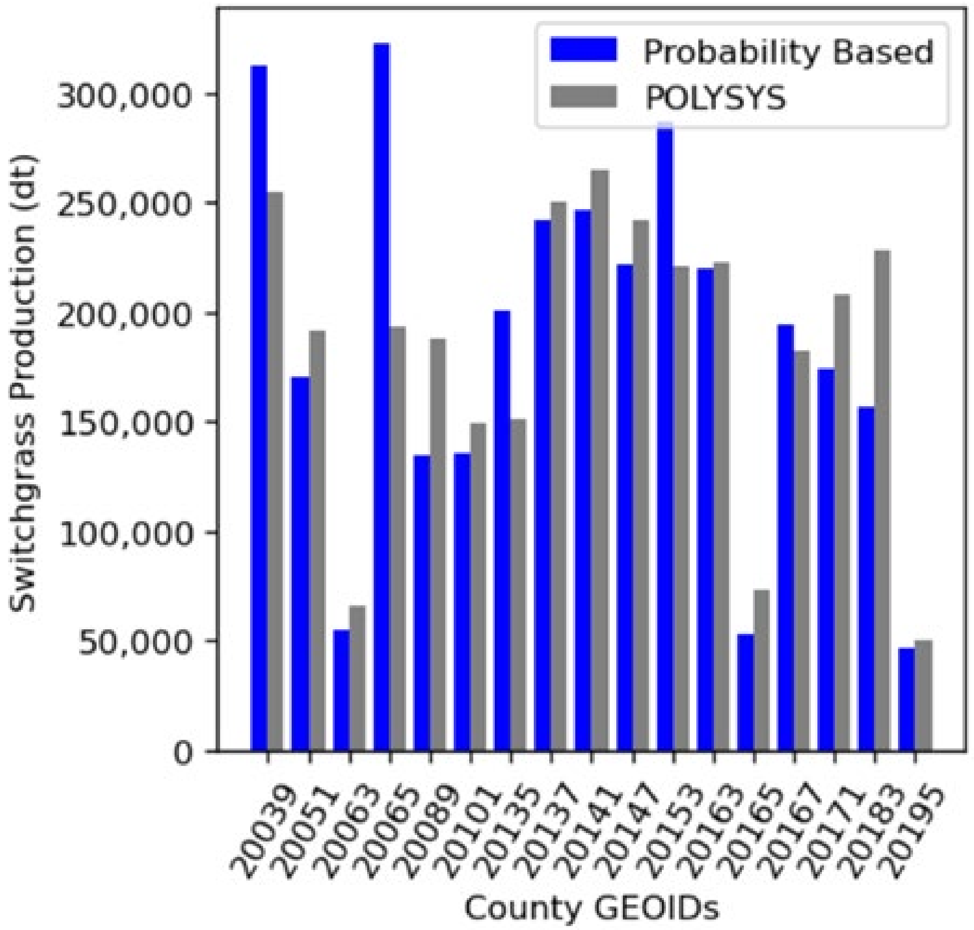
$$SSI = \sum (f_m W_m) * \prod b_n$$



Progress and Outcomes (cont'd)

Biomass Feedstock Field Allocation

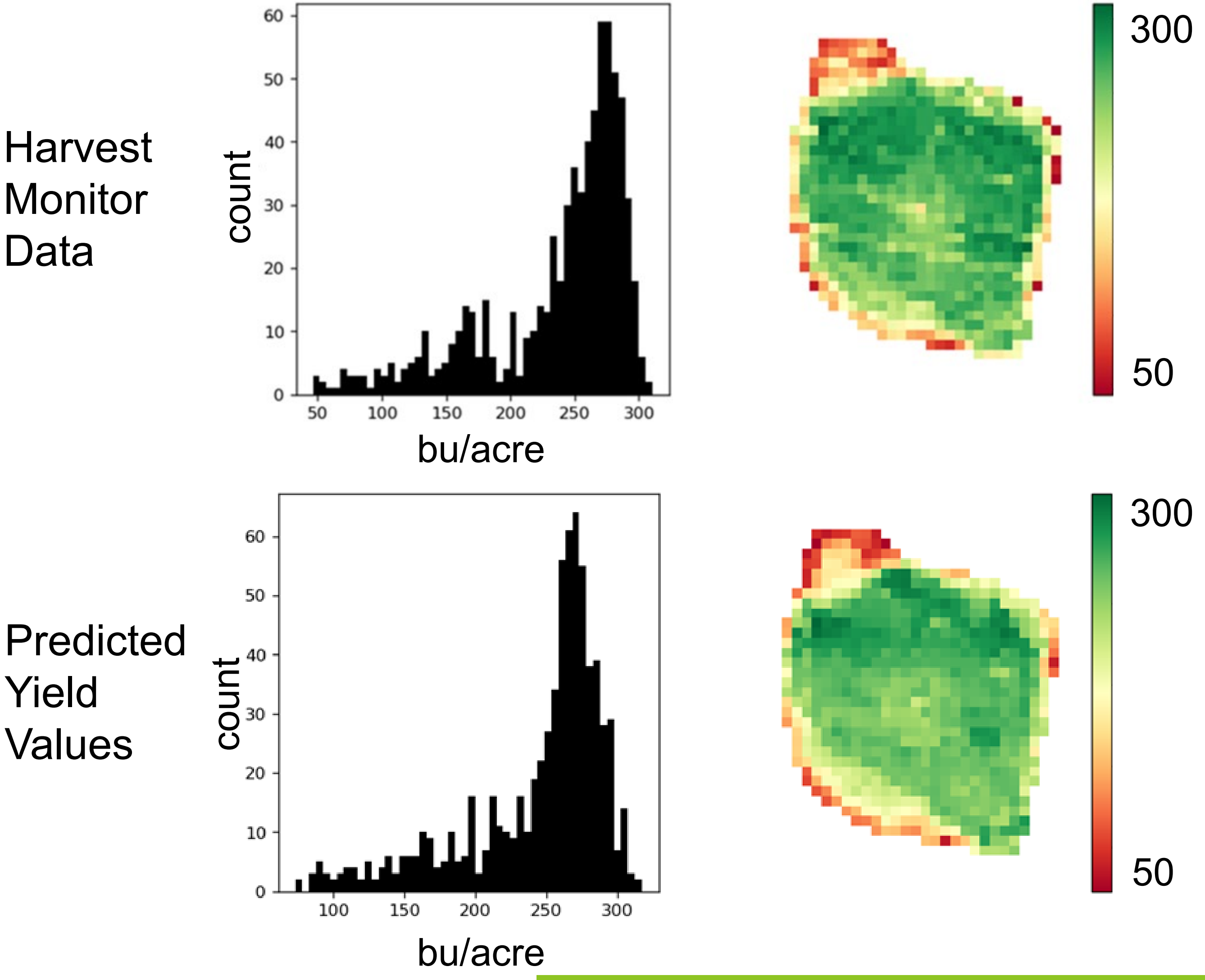
- Allocated modelled biomass feedstock supplies from the Policy Analysis System Model (POLYSYS) to individual fields based on site suitability scores.
- POLYSYS has been used to explore potential future supplies and prices of biomass feedstocks.
- In addition to potential future biomass supplies, an output of POLYSYS is the county-level land-use transition matrix, i.e., the amount of land drawn from and allocated to each crop type in each year.



Progress and Outcomes (cont'd)

Crop Yield Prediction (Crop AIQ)

- Developed modelling capabilities to predict subfield row-crop yields.
- Incorporates publicly available satellite imagery and artificial neural networks to generate crop yield maps needed for subfield design.
- Yield maps of this quality traditionally have been very difficult to acquire without direct contact with farmers.

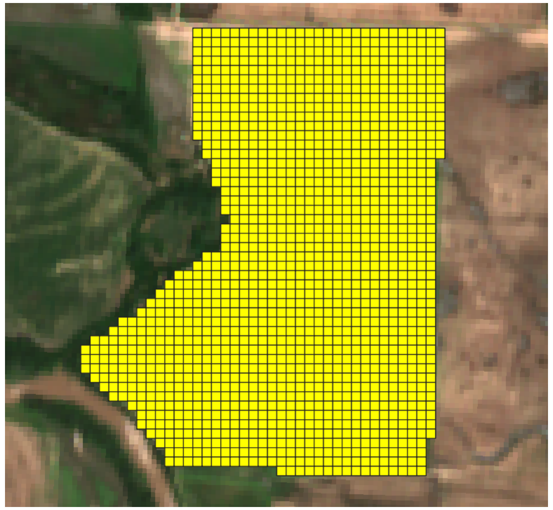


Progress and Outcomes (cont'd)

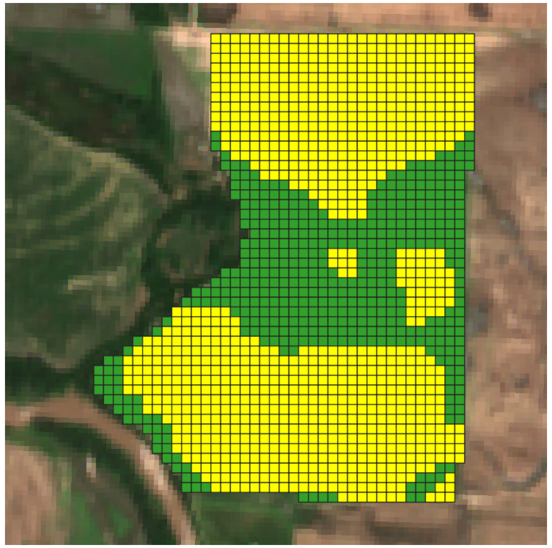
Subfield Crop Allocation

- Constructed a geospatial evolutionary genetic algorithm to find optimal subfield designs for the integration of dedicated energy crops using multiple criteria.
- Incorporates economic and environmental criteria along with user-defined parameters to generate subfield designs allocating energy crops to environmentally vulnerable and economically disadvantaged areas.

$$Field\ Revenue = \sum_{i=0}^{2}\left[R_i \times Y_i - \left(C_{M_i} + C_{O_i} * \frac{FE_{r_i}}{FE_{s_i}}\right)\right] * A_i$$



Baseline Revenue (corn only): $3,422.03



ILM Design Revenue (corn-yellow; switchgrass-green): $4,563.60

- switchgrass access cost reduced by 30% from the SOT estimate

Summary

- From previous analyses, data needs and capability gaps were identified and prioritized to support project goals.
- Needed data and capabilities were developed to support modelled pathways to reduce biomass feedstock access costs by **30 percent**.
  - Field efficiency, site suitability, modelled supply allocation, crop yield prediction, optimization of subfield allocation
- This project has generated/contributed to peer-reviewed publications, technical reports, conference proceedings, a patent application, and a R&D 100 award.
- This project and team are well-positioned to support advanced supply chain development in woody and additional domains (i.e. MSW).

Quad Chart Overview

Timeline

- Project start date: 10/01/2017
- Project end date: 9/30/2020

	FY20	Active Project
DOE Funding	(10/01/2019 – 9/30/2020)	$900,000

Barriers addressed

- At-E. Quantification of Economic, Environmental, and Other Benefits and Costs
- Ft-A. Feedstock Availability and Cost

Project Goal

The goal of this project is to demonstrate through modelling that Integrated Landscape Management can reduce biomass feedstock access costs by at least 20 percent at a field level while improving economic and environmental sustainability outcomes.

End of Project Milestone

Using multi-objective optimization framework, show advanced ILM designs where optimization reduced biomass feedstock production costs by at least 20% through improvements in field operations efficiency, environmental sustainability, and aggregate field net revenue.

Questions

Additional Slides

Responses to Previous Reviewers' Comments

Weakness: Early in the presentation agricultural producers and land managers are identified as potential major suppliers of biomass materials for energy conversion - how is this research going to be disseminated to these stakeholders?	This is an excellent point. Part of the future work scope it to develop novel pathways to develop this type of analysis and results to stakeholders to support the development of a bioeconomy.
Weakness: It's not entirely clear what the actual future work is ("develop subfield yield variability prediction models"). Also, the PIs only acknowledge that if their improved models work (i.e. a "go"), they will be incorporated into LEAF, they omit much larger potential benefits (e.g. aforementioned scalability). The PIs may also want to consider the newly available USDA NCCPI (National Commodity Crop Productivity Index) data, it may be helpful. I'm very interested in the western Nebraska results, where a lot of the sensitive land that may be converted to support biomass production are found. I'd like to see the Pis dig into those results further.	The NCCPI data has been a core component of delineating inter- and intra-field crop yield metrics and variability. However, it is a "static" metric that is not often updated and is not suitable for irrigated agricultural systems. Development of new yield modelling capabilites derived from electromagnetic reflectance signals captured at global scales returned from real crop phenology states provide a higher and more accurate assessment of crop yield at a high spatial/temporal resolution. This, in turn, will make ILM more industrially relevant to agricultural stakeholders.
Go/No-Go Develop subfield yield variability prediction model based upon remotely sensed data of standing crop parameters. Compare against baseline subfield yield estimates derived from SSURGO data.	The Go/No-Go decision point was met on March 31, 2019 with the successful development of the crop yield prediction model (Crop AIQ).

Publications, Patents, Presentations, Awards, and Commercialization

Griffel, L. Michael, Hartley, Damon S., Lin, Yingqian, and Langholz, Matthew. (2021). Integrated Landscape Management to Reduce Biomass Feedstock Access Costs. Web. https://www.osti.gov/biblio/1756895-integrated-landscape-management-reduce-biomass-feedstock-access-costs.

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, p.105088. DOI: 10.1016/j.compag.2019.105088.

Toba, A. L., Griffel, L. M., & Hartley, D. S. (2020). Devs based modeling and simulation of agricultural machinery movement. Computers and Electronics in Agriculture, 177, 105669. doi.org/10.1016/j.compag.2020.105669.

Griffel, L. M., Hartley, D. S., & Lin, Y., (2020). Multi-Criteria Land Suitability Analysis: Identifying Areas to Deploy Integrated Landscape Management for Bioenergy Feedstock Production. International Congress on Sustainability Science and Engineering. August 3 – 5.

Griffel, L. M., Hartley, D. S., & Kunz, M. R., (2019). Spatial Agricultural Crop Yield Prediction Using Remote Sensing Data and Artificial Neural Networks. US Patent Application No. 16/550,081, BEA Docket No. BA-1115.

Griffel, L.M., Hartley, D. S., & Oldemeyer, Tessica A. G., (2019). Exploring the Potential of Machine Learning/Vision to Map Subfield Crop Yield Variability in Agricultural Production Systems Using Remote Sensing Data. ASABE Annual International Meeting. July 7 – 10.

Griffel, L. M., Hartley, D. S., & Kunz, M. R., (2020). Crop Artificial Intelligence Quotient (Crop AIQ). R&D 100 Award.