2013 DOE Bioenergy Technologies Office (BETO) Project Peer Review

1.1.1.2 Sustainable Feedstock Production-Logistics Interface

May 23, 2013
Sustainability and Analysis Platform

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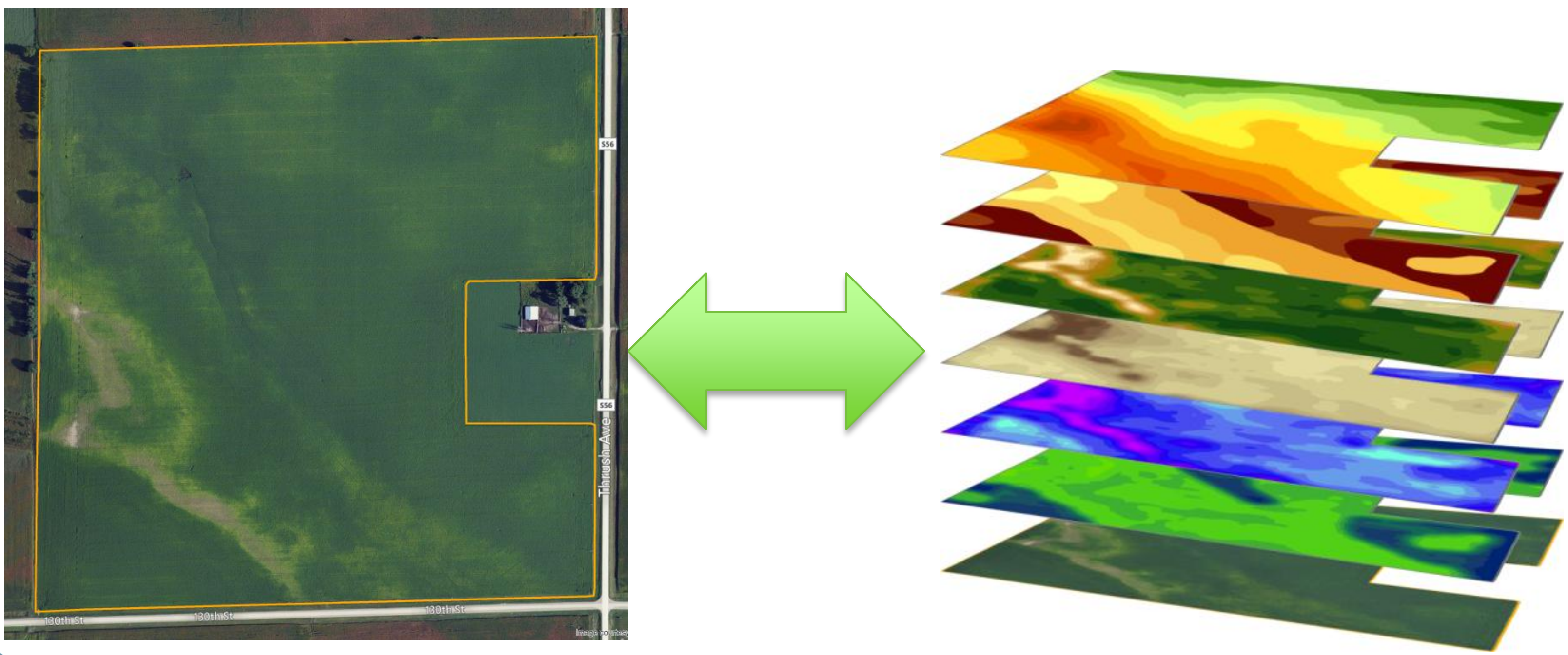
Idaho National Laboratory

Goal Statement

- Develop integrated biomass production system designs that:
  - Increase total productivity of the landscape
  - Decrease delivered feedstock cost
  - Increase production system environmental performance



Project Quad Chart Overview

Timeline

- Project start date: 10/01/2011
- Project end date: 09/30/2017
- Percent complete: 40%

Barriers

- Ft-A. Feedstock Availability and Cost
- Ft-B. Sustainable Production
- Ft-D. Sustainable Harvesting

Budget

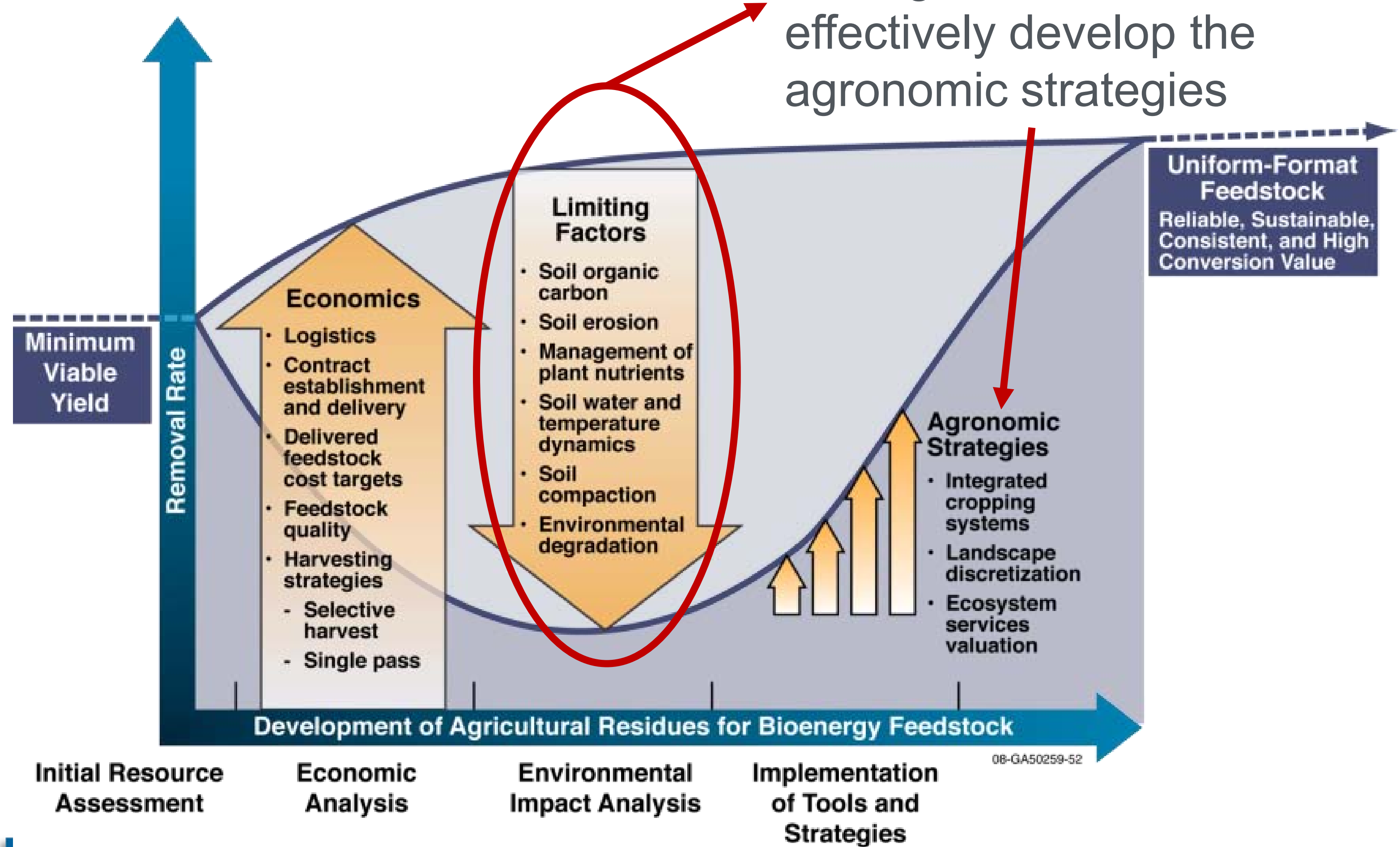
- Total Funding = $600,000
  - DOE share – 100%
  - Contractor share – 0%
- Funding in FY11 = $300,000
- Funding in FY12 = $300,000

Partners

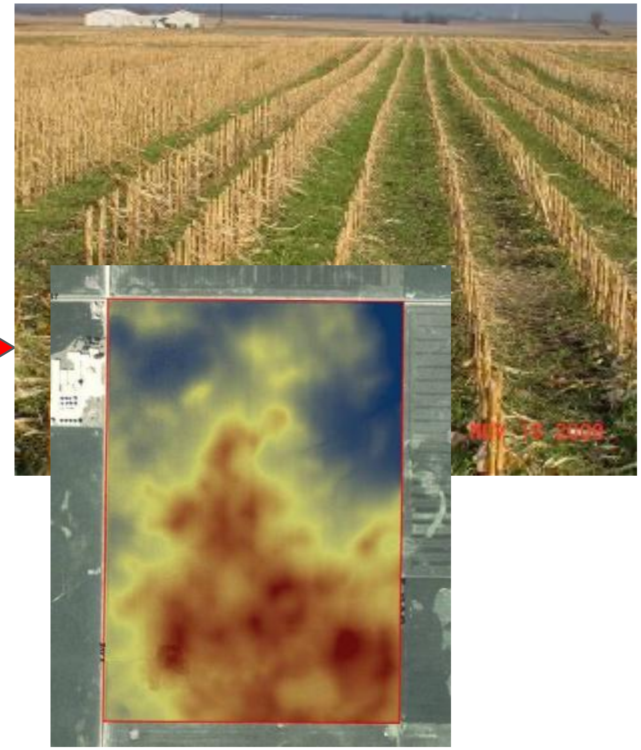
- DOE Regional Feedstock Partnership
- USDA ARS
- USDA NRCS
- Iowa State University
- Colorado State University
- Enersol Resources

Project Overview

Focused on quantifying the limiting factors, so we can effectively develop the agronomic strategies



1 - Approach



The models and databases exist,
We need a framework where models can plug together to answer our questions.

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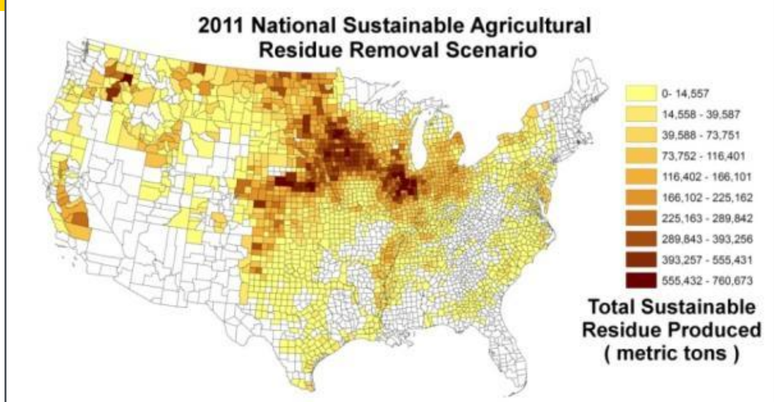
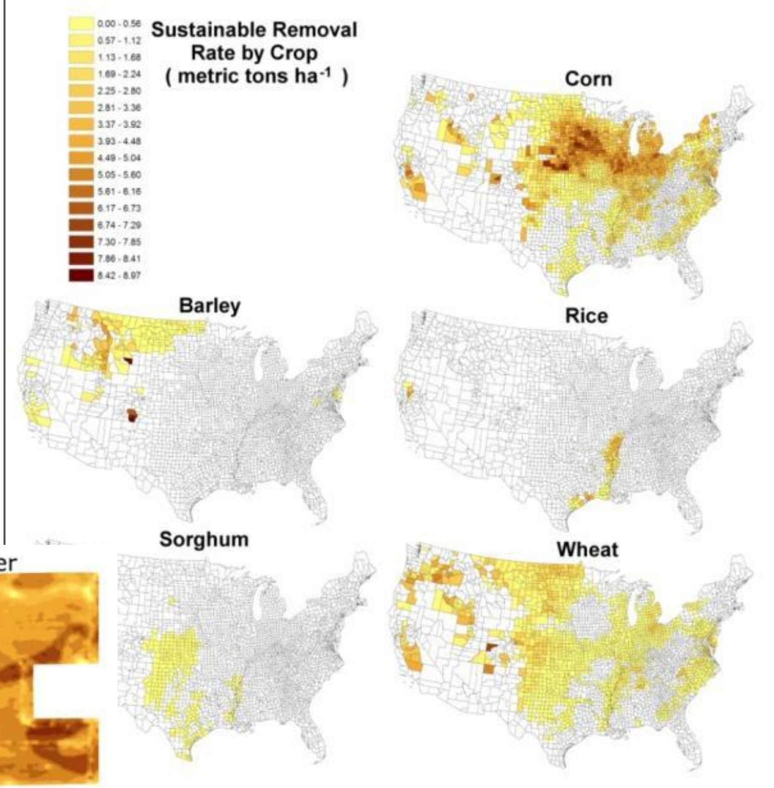
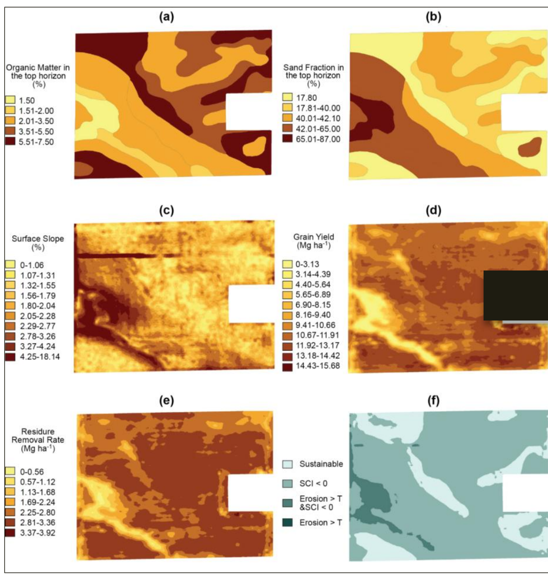
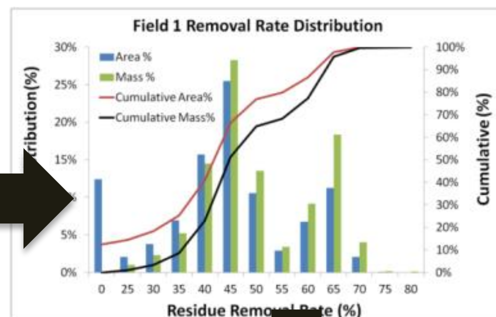
Key Products to Date

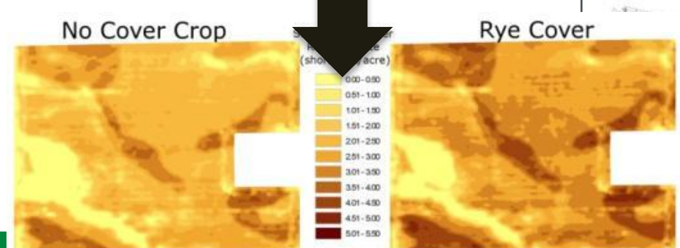
- National Assessment
- Sub-field Decision Framework
- Variable Rate Impact Quantification
- Effective Decision Support Tool











2 – Technical Progress: National Assessment Results

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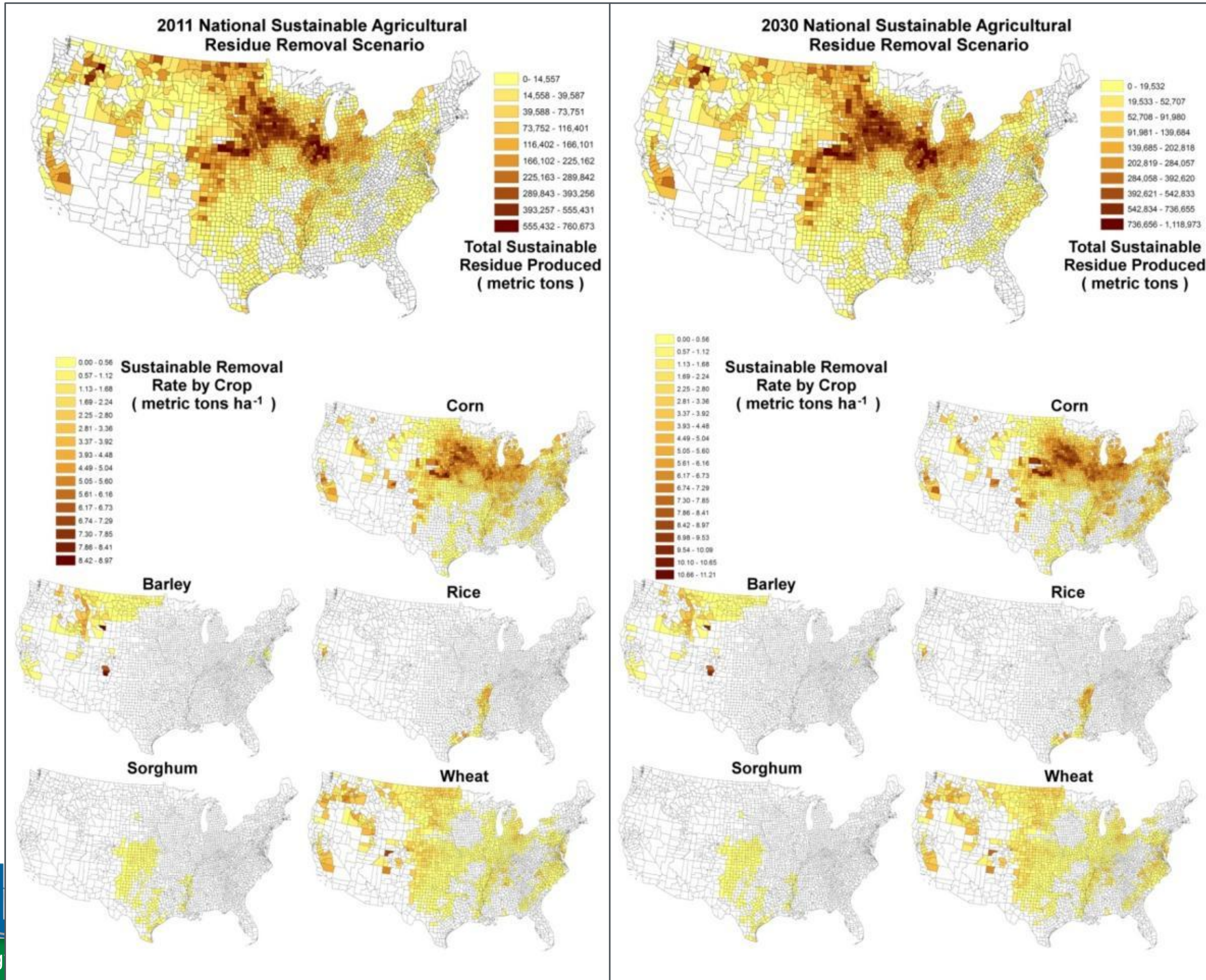

2 – Technical Progress: National Assessment: Results

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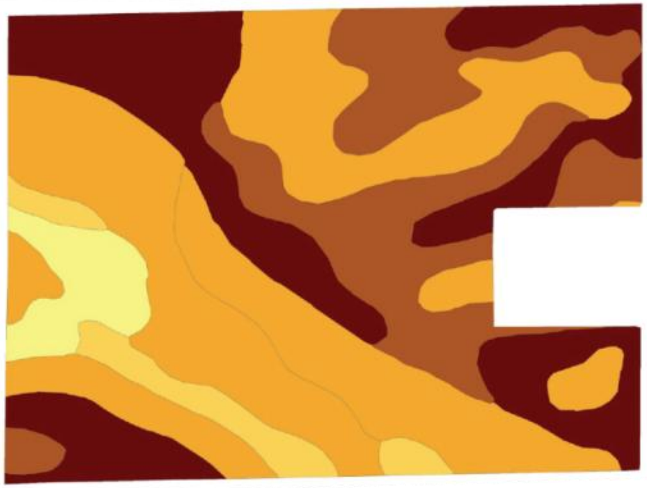
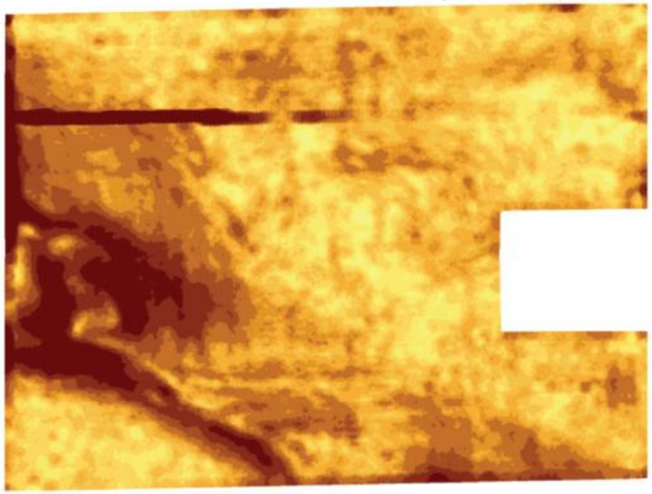
State	2011 Sustainable Residue (metric tons)	2030 Sustainable Residue (metric tons)	Percentage Increase from 2011 to 2030	2030 Sustainable Residue – All No Till Assumption (metric tons)
IA	25,916,452	37,320,712	44%	49,761,379
IL	20,934,715	29,995,334	43%	44,070,875
NE	18,608,878	25,147,128	35%	31,542,110
MN	16,005,783	21,251,610	33%	27,925,458
IN	8,614,653	12,457,194	45%	18,217,545
SD	9,215,154	11,436,652	24%	12,889,524
ND	7,332,947	8,614,473	17%	10,953,330
OH	5,686,982	8,225,276	45%	10,620,349
KS	6,491,175	8,170,214	26%	13,155,859
WI	4,261,587	6,391,914	50%	11,589,503
MI	3,200,437	4,375,145	37%	7,219,949
TX	2,282,048	3,342,113	46%	7,296,466
MO	2,251,692	3,303,103	47%	6,456,004
……	……	……	……	……
US Total	**150,897,178**	**207,905,224**	**38%**	**297,499,383**

2 – Technical Progress: Variability at the Sub-Field Scale

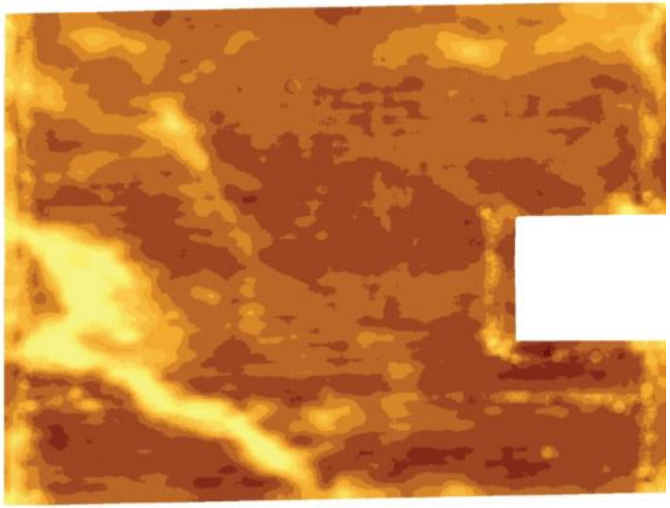
Soil Characteristics



Surface Topography



Grain Yield



2 – Technical Progress: Sub-Field Scale Variability

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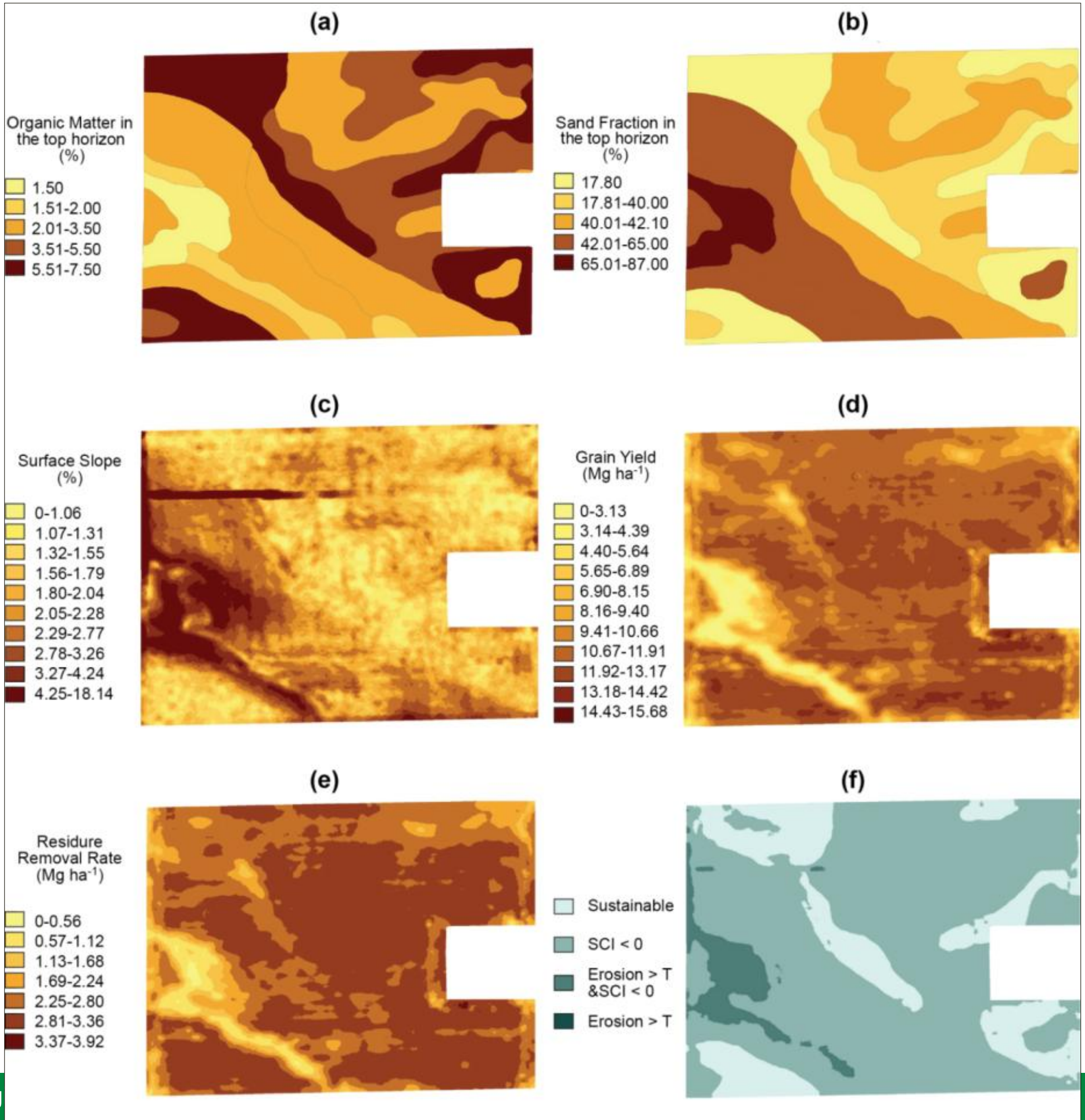

Field 1

INL

Implementing Sustainable Harvest: Sub-Field Scale Variability

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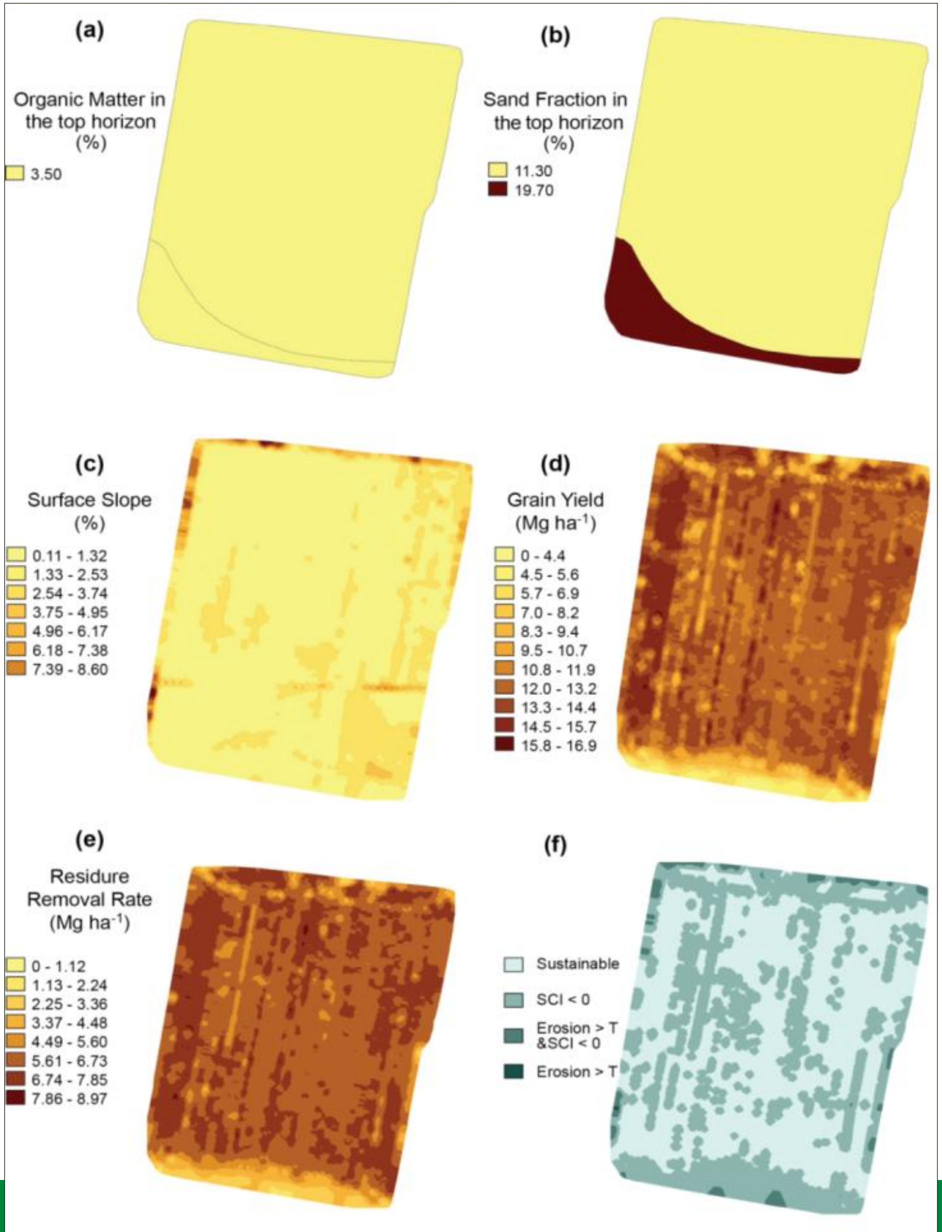

Field 2

INL

Implementing Sustainable Harvest: Sub-Field Scale Variability

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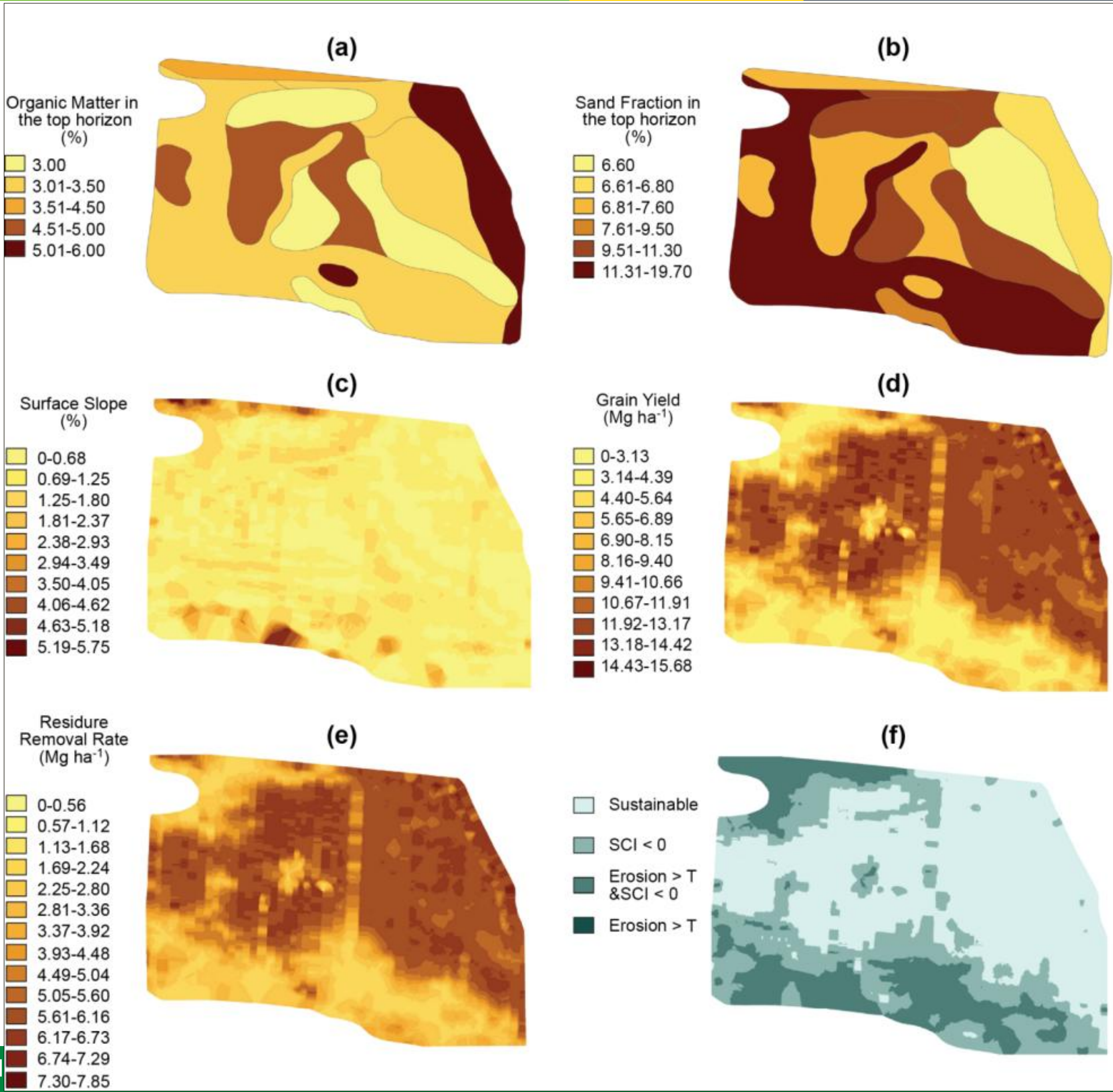


Field 3

2 – Technical Progress:

NRCS Conservation Planning and Sub-Field Variability

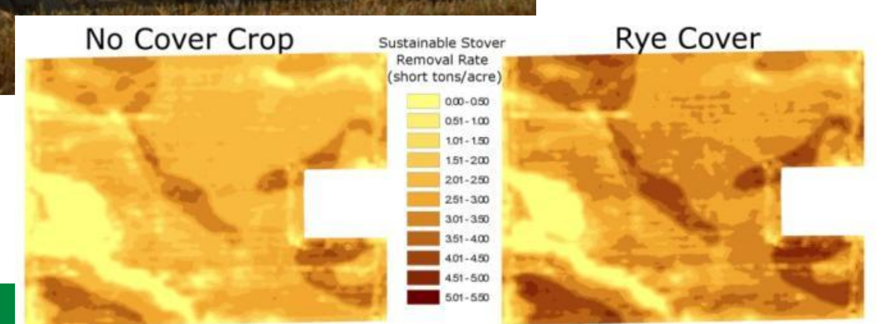
Field	Field Ave. Yield (Mg ha^{-1})	Tillage	Rot.	Residue Harvest Op's.	Rem. Rate (Mg ha^{-1})	Comb. Eros. (Mg ha^{-1})	T Value (Mg ha^{-1})	SCI
1	10.85	Red.	Corn-Soy.	Rake and Bale	2.68	6.53	11.21	-0.15
2	12.60	Red.	Cont. Corn	Rake and Bale	6.46	2.14	11.21	0.33
3	12.40	Conv.	Cont. Corn	Rake and Bale	5.10	7.54	11.21	0.01

Field	Total Mg Removed	Mg Removed Sustainably	Total Field Area (ha)	Area Managed Sustainably
1	152	23%	57	21%
2	119	89%	19	83%
3	387	72%	77	62%

2 – Technical Progress: Residue Removal Implementation

Sustainable management options

- Lower removal rates via equipment choice or interval removal schemas
- Advanced equipment development, i.e. variable rate
- Agronomic strategies
  - Tillage
  - Cover crops
  - Landscape management concepts



2 – Technical Progress: Tillage Impacts in Iowa

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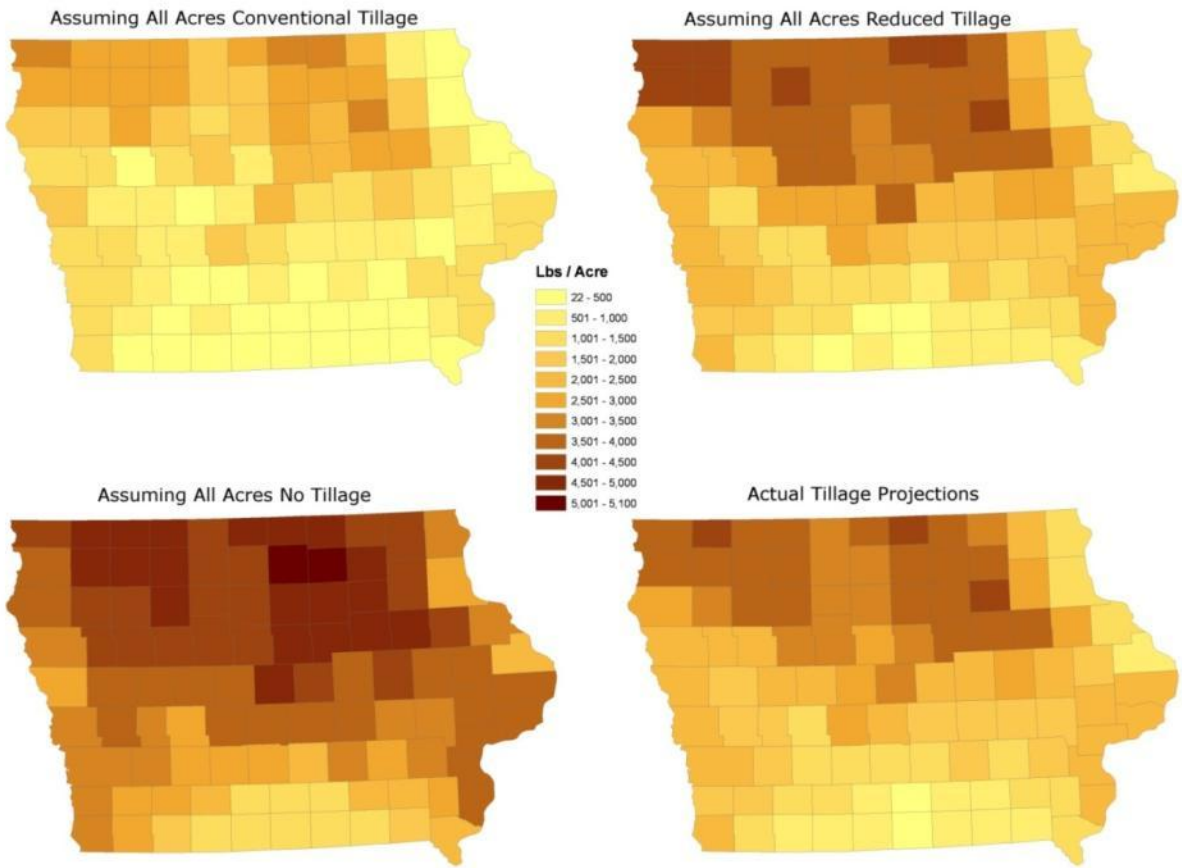

	State Average Yield (tons/acre)	Tonnage Weighted Average Yield (tons/acre)	Total Residue (tons)	Sustainably Harvestable as Percentage of Total Residue Produced
Conventional Tillage	0.65	1.01	16,684,931	15%
Reduced Tillage	1.19	1.56	30,218,151	28%
No Tillage	1.78	2.00	43,157,338	40%
Actual Tillage	1.16	1.48	29,190,729	27%

2 – Technical Progress:
Sub-Field Scale Variability in Removal Rate

- Next generation removal concepts
- Modeled from existing systems with additional performance assumptions
- Assumed to dynamically adjust from 25% to 80% removal

2 – Technical Progress: Variable Rate Removal

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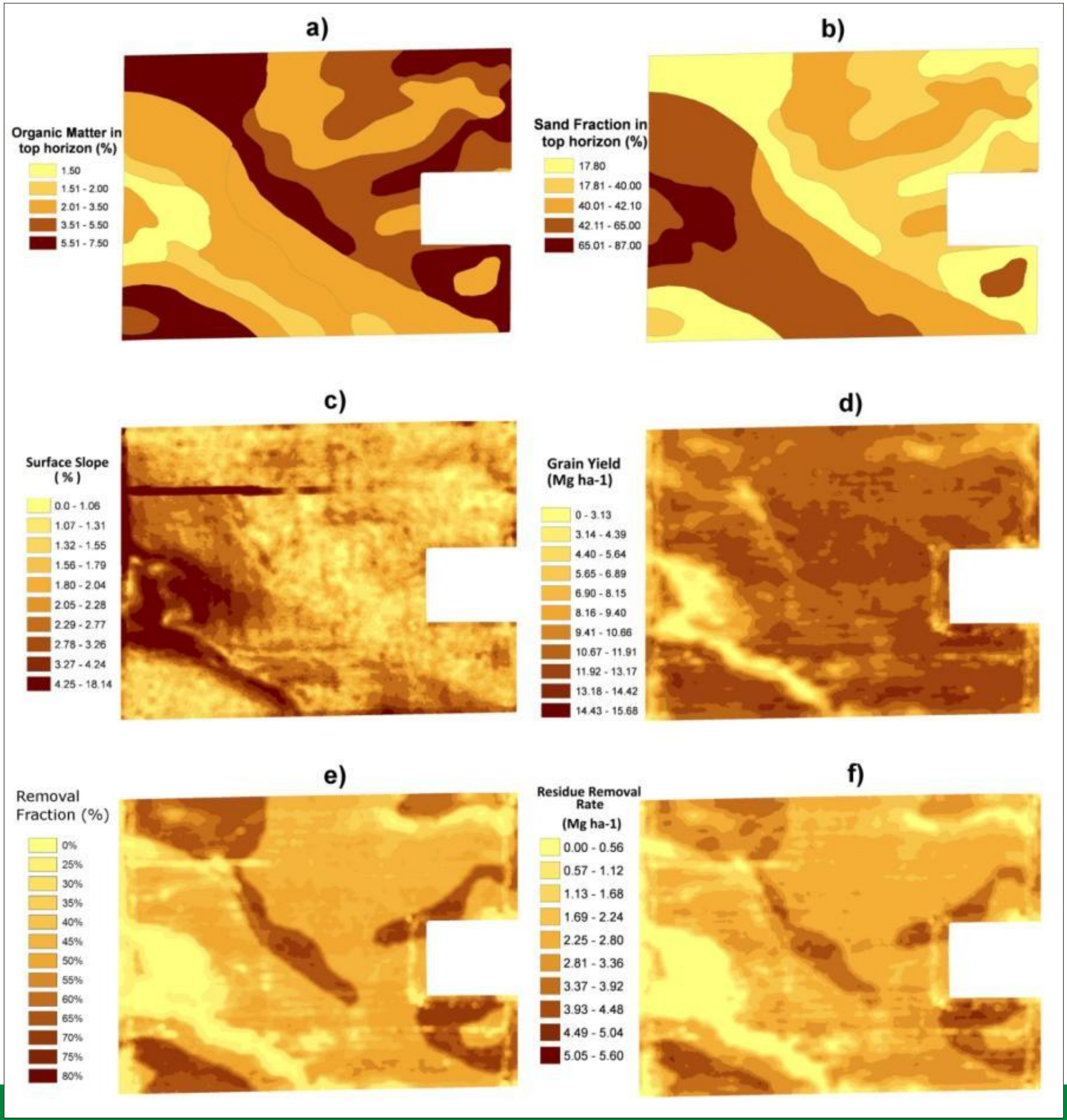
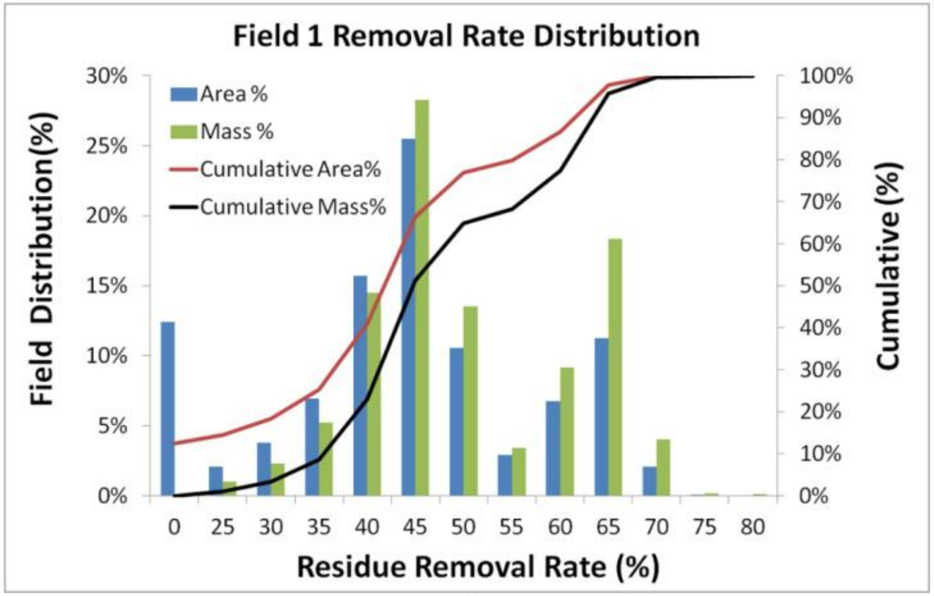
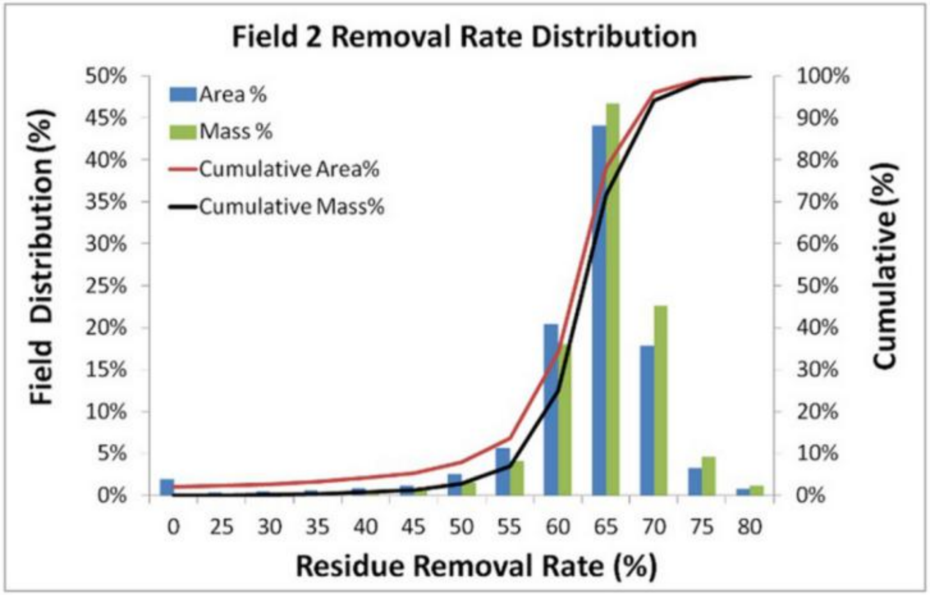
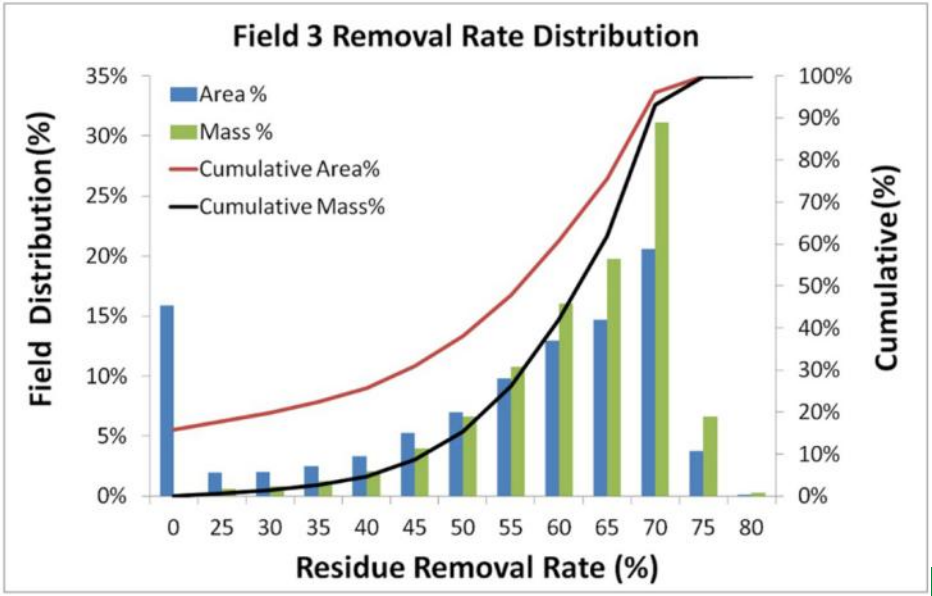


Field 1

2 – Technical Progress: Variable Rate Removal







2 – Technical Progress: Agronomic Strategies - Cover Crops

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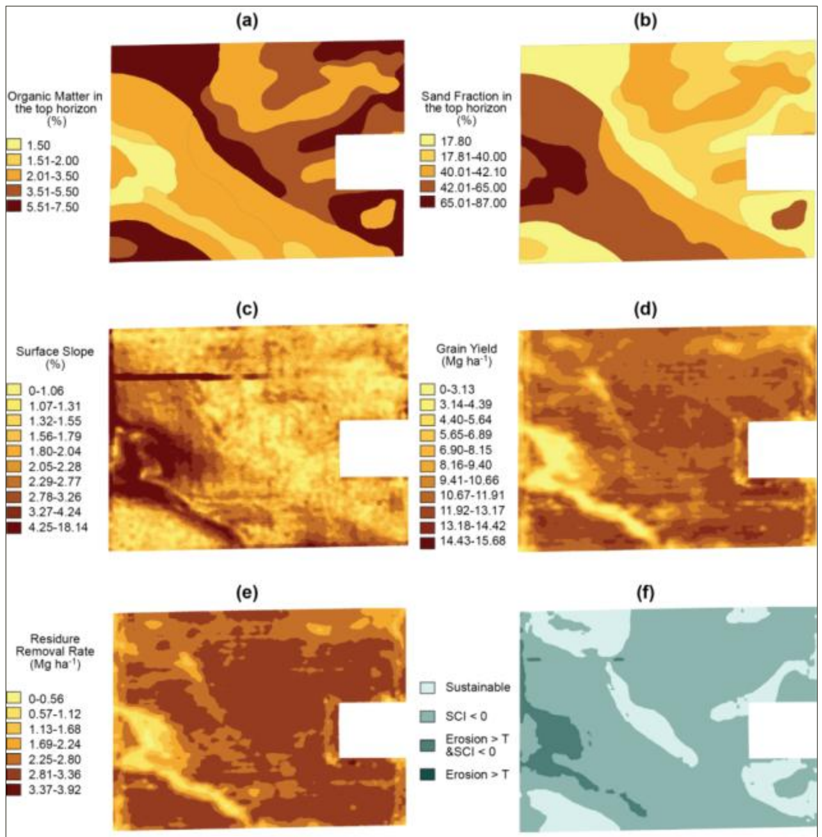
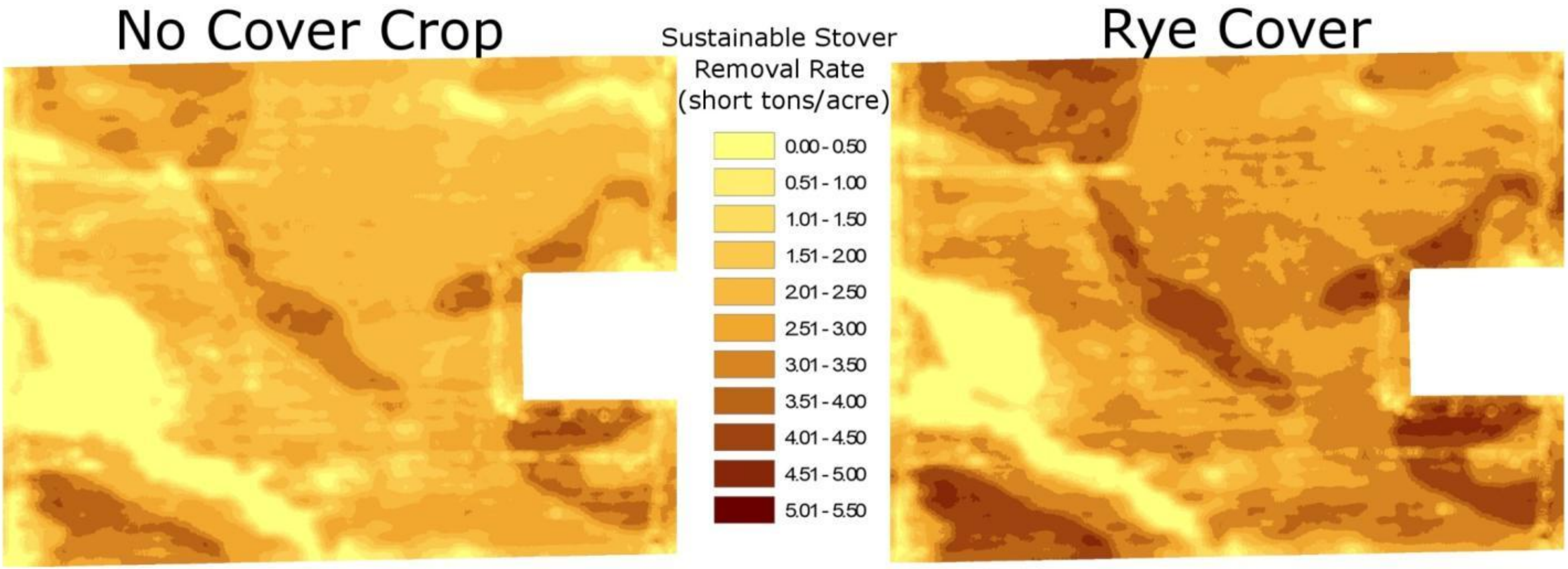
Rake and Bale Removal	No Cover Crop			Rye Cover Crop		
	Total Annual Sustainable Residue (short tons)	Percentage of Field Managed Sustainably	Annual Soil Loss (short tons)	Total Annual Sustainable Residue (short tons)	Percentage of Field Managed Sustainably	Annual Soil Loss (short tons)
Reduced Tillage	39	21%	336	297	83%	194

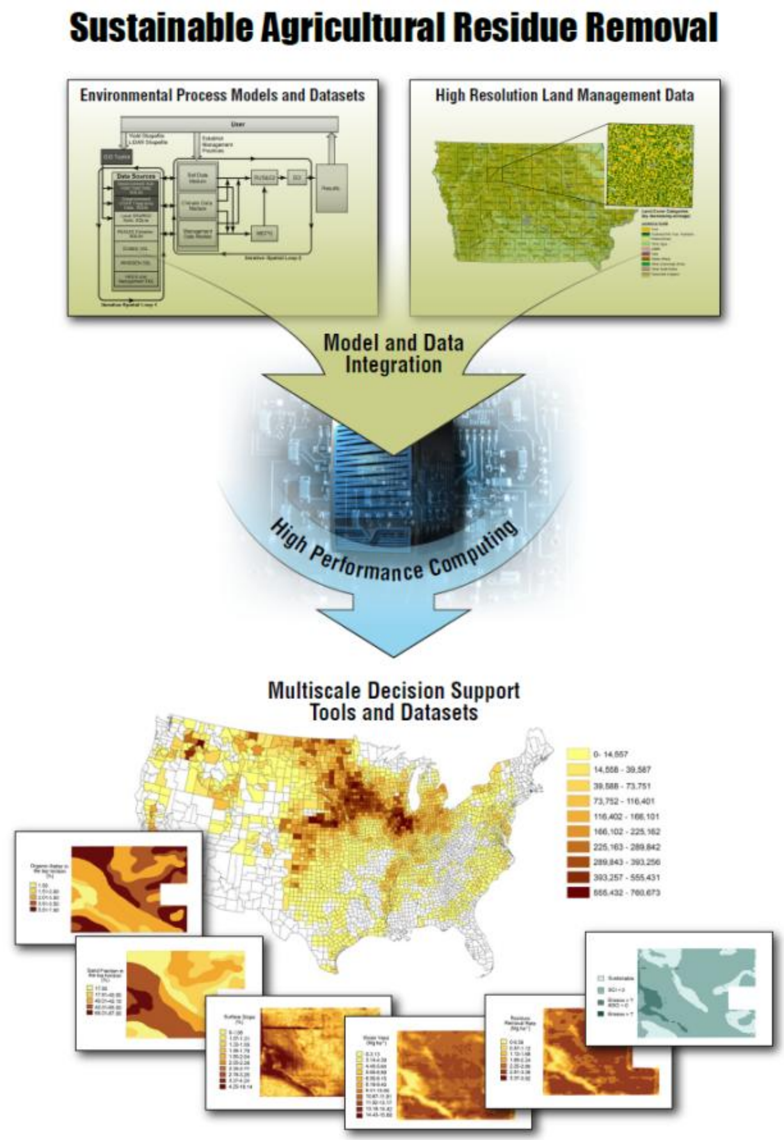


2 – Technical Progress:
Agronomic Strategies – Putting it all together

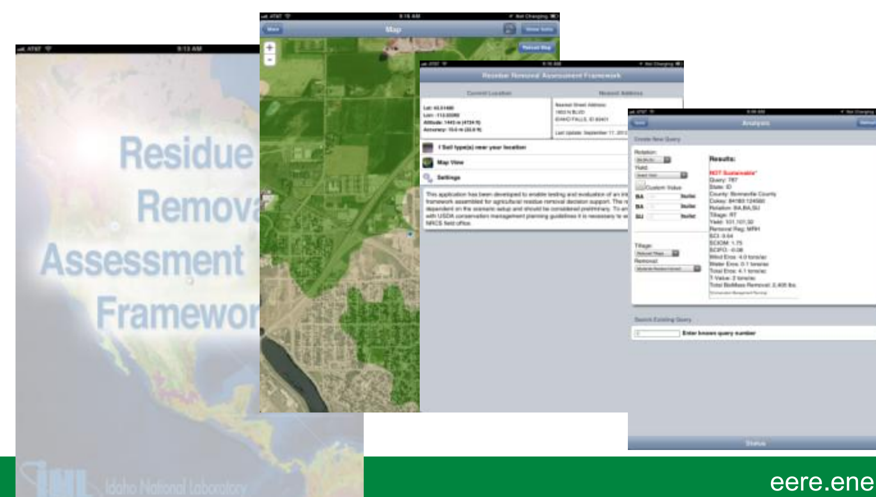


	No Cover Crop			Rye Cover Crop		
	Total Annual Sustainable Residue (short tons)	Sustainable Residue Removal Rate (short tons / acre)	Annual Soil Loss (short tons)	Total Annual Sustainable Residue (short tons)	Sustainable Residue Removal Rate (short tons / acre)	Annual Soil Loss (short tons)
Reduced Tillage	293	2.10	279	392	2.80	240
No Tillage	331	2.36	175	418	2.99	118

2 – Technical Progress: Current Deployments

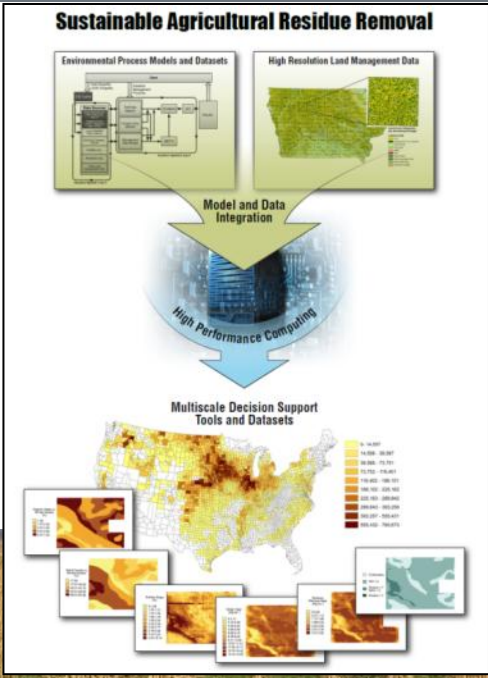


- SustainR2 Mobile App
    - iOS version available in Apple App Store
    - URL: http://bioenergyldt.inl.gov/mobile
- Map Selection Webtool: beta testing on INL network
- Model Integration and Data Management Core Code Libraries
    - Downloadable from google code project LEAF (Landscape Environmental Assessment Framework)



3 – Relevance

- Developed spatially comprehensive multi-factor agricultural residue assessment for Billion Ton Update
- Deployed decision tools that reconcile NRCS conservation planning with residue removal decisions
- Identified sub-field challenges for residue removal decisions and developed a now widely accepted toolset
- Analytics guiding development of advanced engineered systems for precision residue removal
- Model effort for collaboration between DOE/USDA/Universities/ private sector partners
- Effective Decision Support Tool



4 – Critical Success Factors

Success Factors

- Engaging data collectors to provide datasets and analytics that fill current gaps
- Engaging certification focused efforts to provide analytic support that meets certification standards

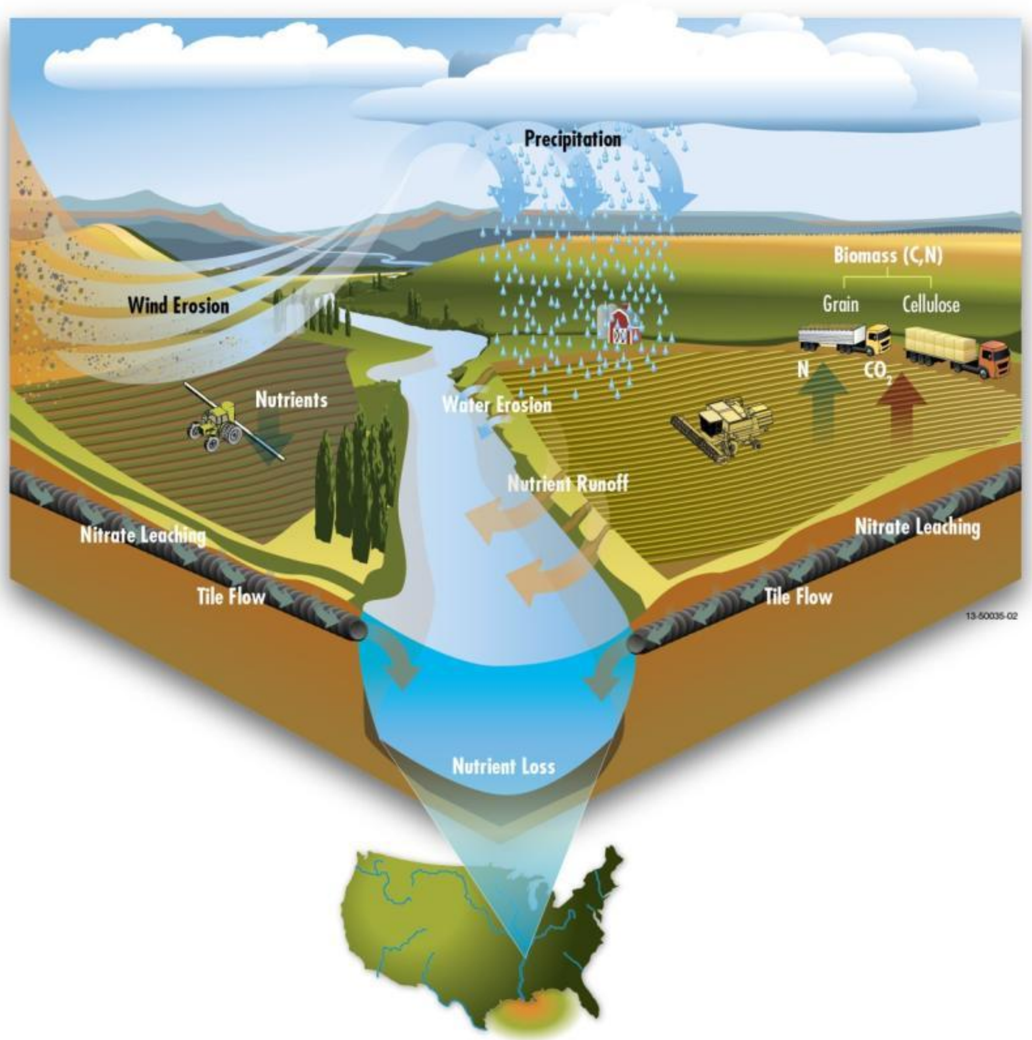
Potential Challenges

- Keeping up with deployment demands
- Beginning to work with parameters that are less effectively modeled
- Ending field trial work

Advancing the State of Technology

- Using integrated environmental process modeling to make landscape design decisions
- Cloud based computing for future deployment to cut computational time orders of magnitude
- Building progressive future resource assessments that represent emerging landscape management concepts

5 – Future Work

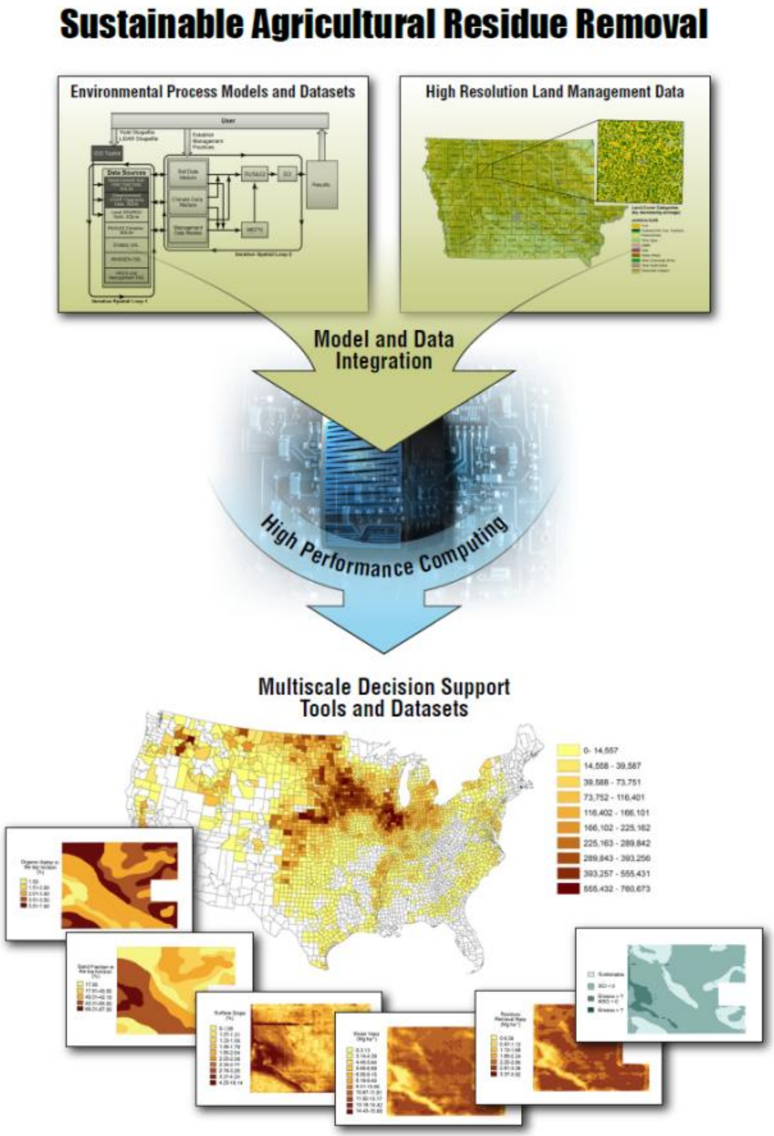


- Integrated landscape design
- Field scale water quality
- Increased predictive capability around N cycles
- Updated national assessment considering integrated landscape management concepts

Summary

Key Products to Date
- National Assessment
- Sub-field Decision Framework
- Variable Rate Impact Quantification
- Effective Decision Support Tool

Current Deployment Pathways
- SustainR2 Mobile App
  - iOS version available in Apple App Store
  - URL: http://bioenergyldt.inl.gov/mobile
- Map Selection Webtool
- Model Integration and Data Management Core Code Libraries
  - Downloadable from google code project LEAF (Landscape Environmental Assessment Framework)



Questions

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Additional Slides

Additional Slides: Publications

- D. Muth, D. McCorkle, J. Koch, and K. M. Bryden, “Modeling the Impact of Variability at the Sub-Field Scale on Sustainable Agricultural Residue Removal,” Agronomy Journal, July 2012,104: 970-981.
- D. Muth and K. M. Bryden, “An Integrated Model for Assessment of Sustainable Agricultural Residue Removal Limits for Bioenergy Systems,” accepted with revision, Environmental Modelling and Software, Available online 11 May 2012, ISSN 1364-8152, 10.1016/j.envsoft.2012.04.006.
- D. Muth and K. M. Bryden, “An Investigation of Sustainable Variable Rate Residue Removal,” Journal of Environmental Quality, Posted May 2012, doi:10.2135/jeq2012.0067.
- D. Muth, R. Nelson, K. M. Bryden, “Sustainable Agricultural Residue Removal for Bioenergy: A Spatially Comprehensive National Assessment,” Applied Energy, doi:10.1016/j.apenergy.2012.07.028
- D. Muth, J. Joch, D. McCorkle, and K. M. Bryden, “A Computational Strategy for Design and Implementation of Equipment that Address Sustainable Agricultural Residue Removal at the Subfield Scale,” submitted to the ASME 2012 Design Engineering Technical Conferences & Computers in Engineering Conference, DETC2012-71430, August 2012, Chicago, IL.
- D. Karlen and D. Muth, "Landscape Management for Sustainable Supplies of Bioenergy Feedstock and Enhanced Soil Quality," In-Press, Agrocencia
- A. English, W. Tyner, J. Sesmero, O. Phillip, and D. Muth, "Environmental Tradeoffs of Stover Removal and Erosion in Indiana," In-Review, Biofuels, Bioproducts & Biorefining, BIOFPR-12-0051.
- J. Koch, D. Muth, and K. Bryden, “An Integrated Modeling and Data Management Strategy for Cellulosic Biomass Production Decisions,” Proceedings of the 2012 International Congress on Environmental Modelling and Software, July 2012, Leipzig, Germany.
- Abodeely, D. Muth, and K. Bryden, “Integration of the DAYCENT Biogeochemical Model within a Multi-Model Framework,” Proceedings of the 2012 International Congress on Environmental Modelling and Software, July 2012, Leipzig, Germany.
- A. English, W. Tyner, J. Sesmore, P. Owens, and D. Muth. "Environmental Impacts of Stover Removal in the Corn Belt," Proceedings of the 2012 Agricultural & Applied Economics Annual Meeting, August 2012, Seattle, WA.
- "Climate Change and Agricultural: Effects and Adaptation." National Climate Assessment Technical Reference Document, United States Global Change Research Program.
- D. Archer, D. Muth, J. Jacobson, and D. Karlen. "Economics of Residue Harvest: Regional Partnership Evaluation," Proceedings of the 2012 National Sun Grant Meeting: Science for Biomass Feedstock Production and Utilization.
- J. Abodeely, D. Muth, P. Adler, E. Campbell, and K.M. Bryden. "A Multi-Factor Analysis of Sustainable Agricultural Residue Removal Potential," Proceedings of the 2012 National Sun Grant Meeting: Science for Biomass.
- K. Kenney, J.R. Hess, W. Smith, I. Bonner, and D. Muth. "Improving Biomass Logistics Cost Within Agronomic Sustainability Constraints and Biomass Quality Targets," Proceedings of the 2012 National Sun Grant Meeting: Science for Biomass.

2 – Technical Progress: The Sub-Field Integrated Framework

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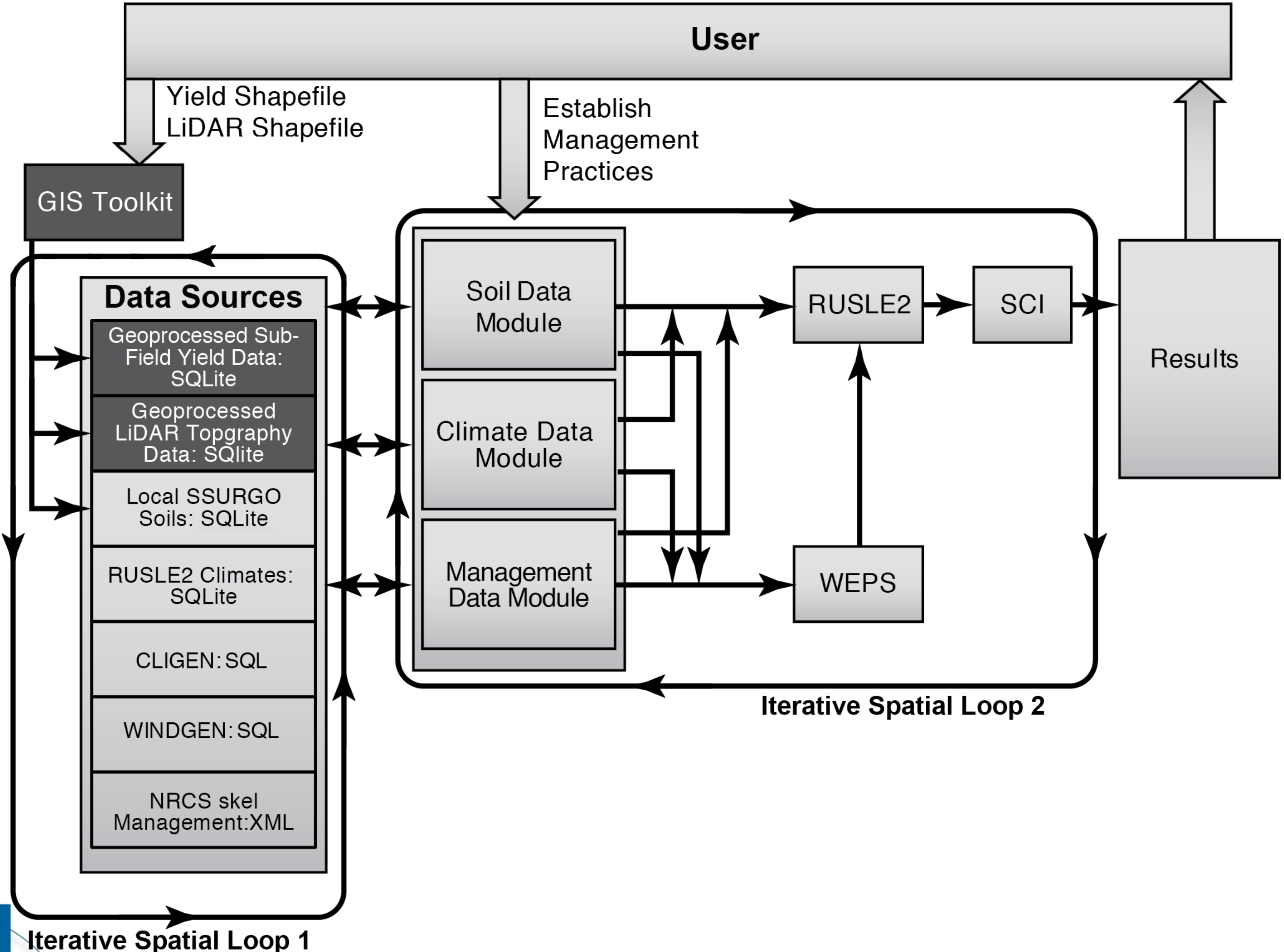

Implementing Sustainable Harvest: Variable Rate Removal

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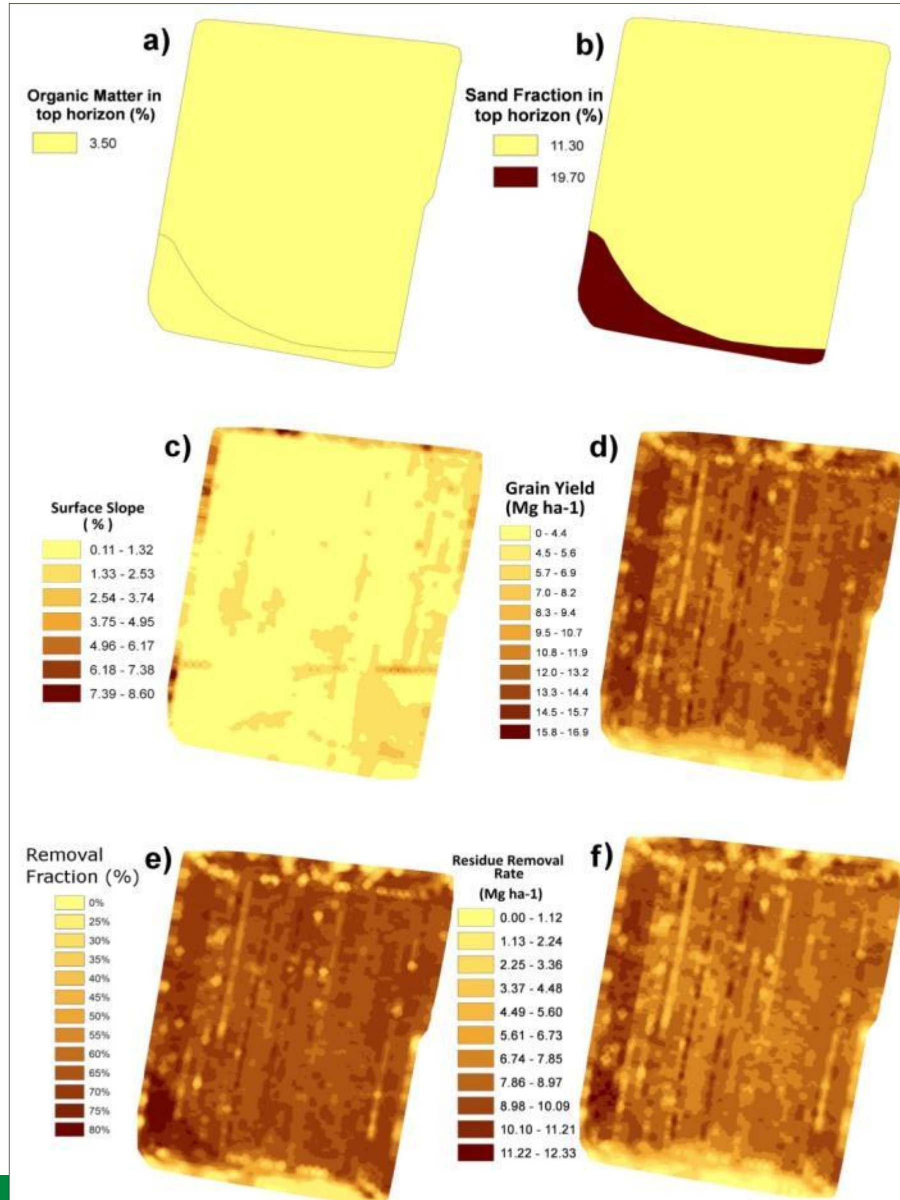
Field 2



Implementing Sustainable Harvest: Variable Rate Removal

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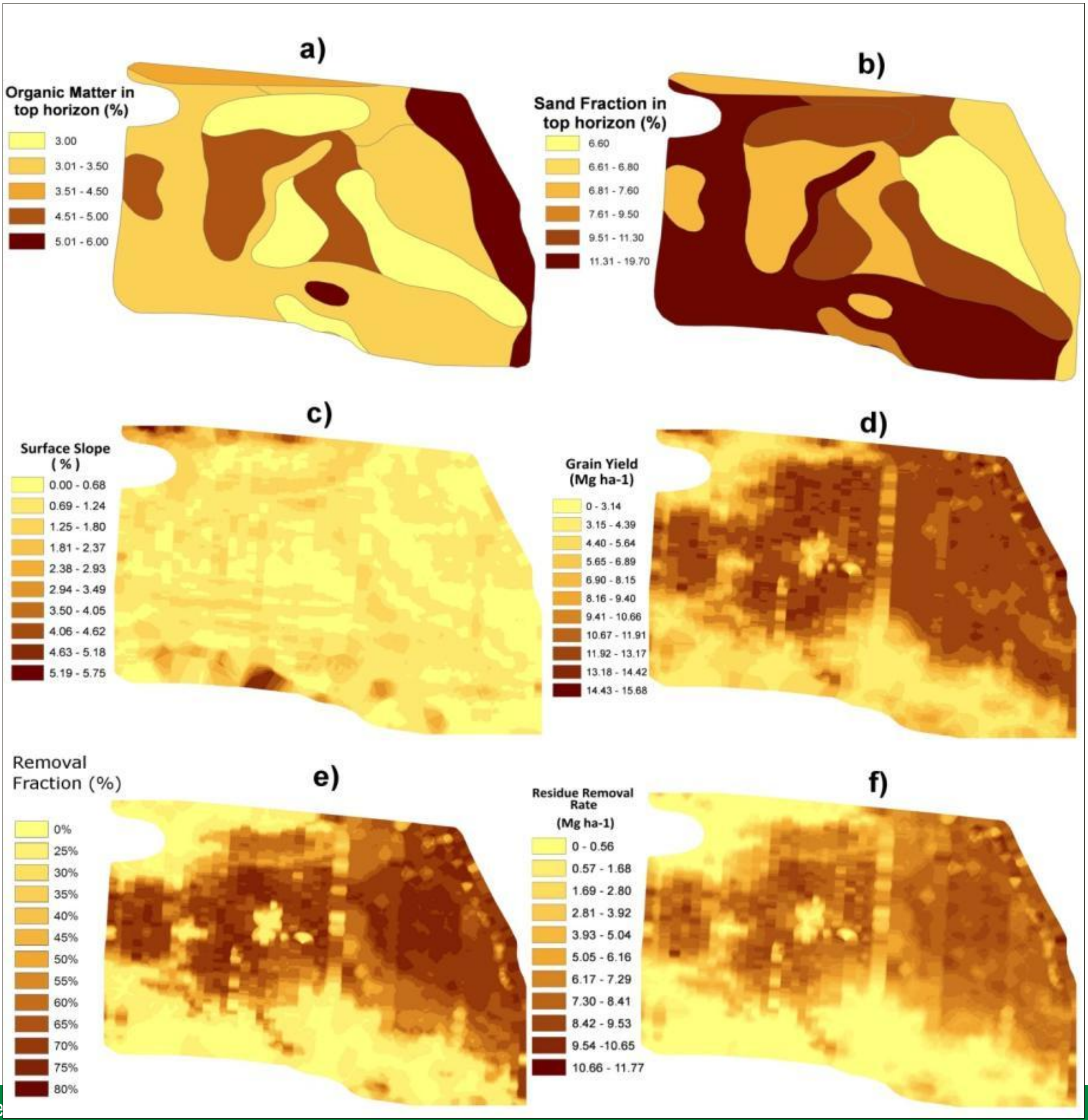

Field 3

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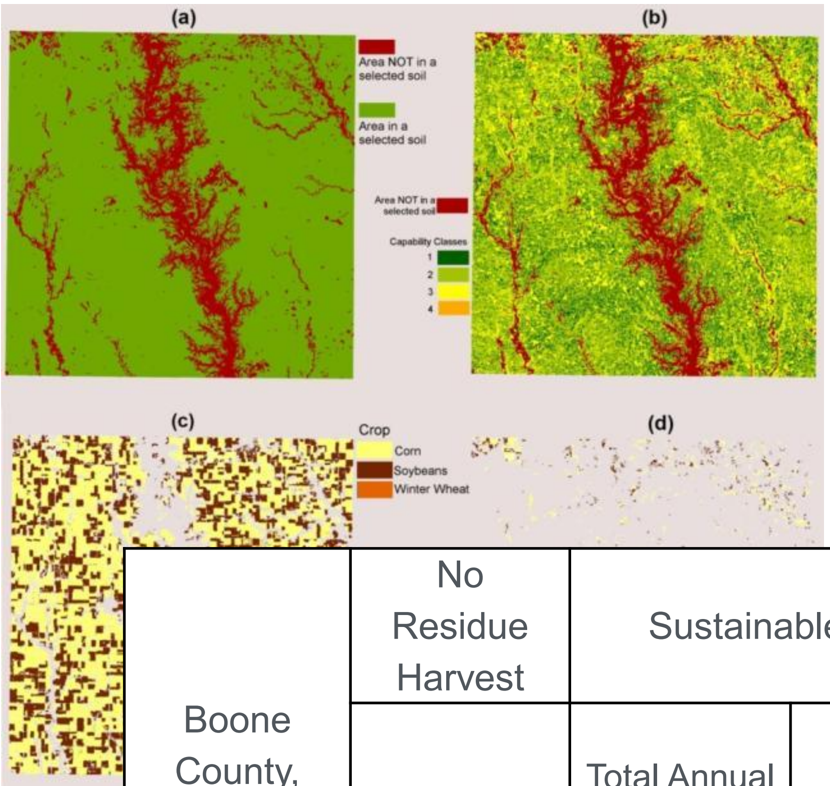
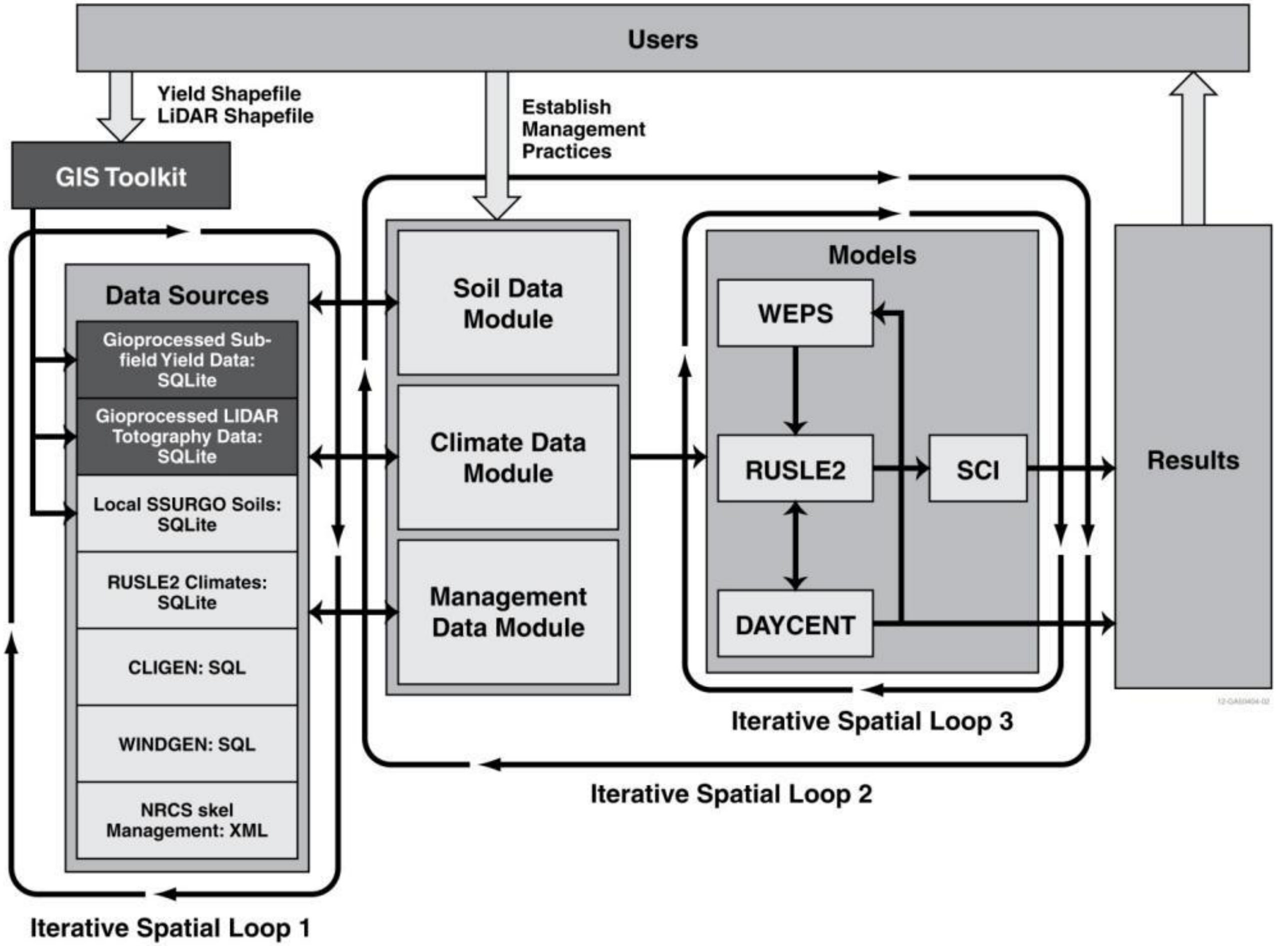
Agronomic Strategies: Large Scale Impacts



Boone County, Iowa	No Residue Harvest	Sustainable Removal Potential			Sustainable Removal Potential with Rye Cover Crop		
	Annual Soil Loss (short tons)	Total Annual Sustainable Residue (short tons)	Average Sustainable Removal Rate (short tons / acre)	Annual Soil Loss (short tons)	Total Annual Sustainable Residue (short tons)	Average Sustainable Removal Rate (short tons / acre	Annual Soil Loss (short tons)
2011 Scenario	512,972	358,616	2.20	613,915	485,228	2.98	349,598
2030 Scenario	382,013	615,351	3.78	517,067	729,905	4.48	292,093

Extended Integrated Modeling Framework



Extended Integrated Modeling Framework

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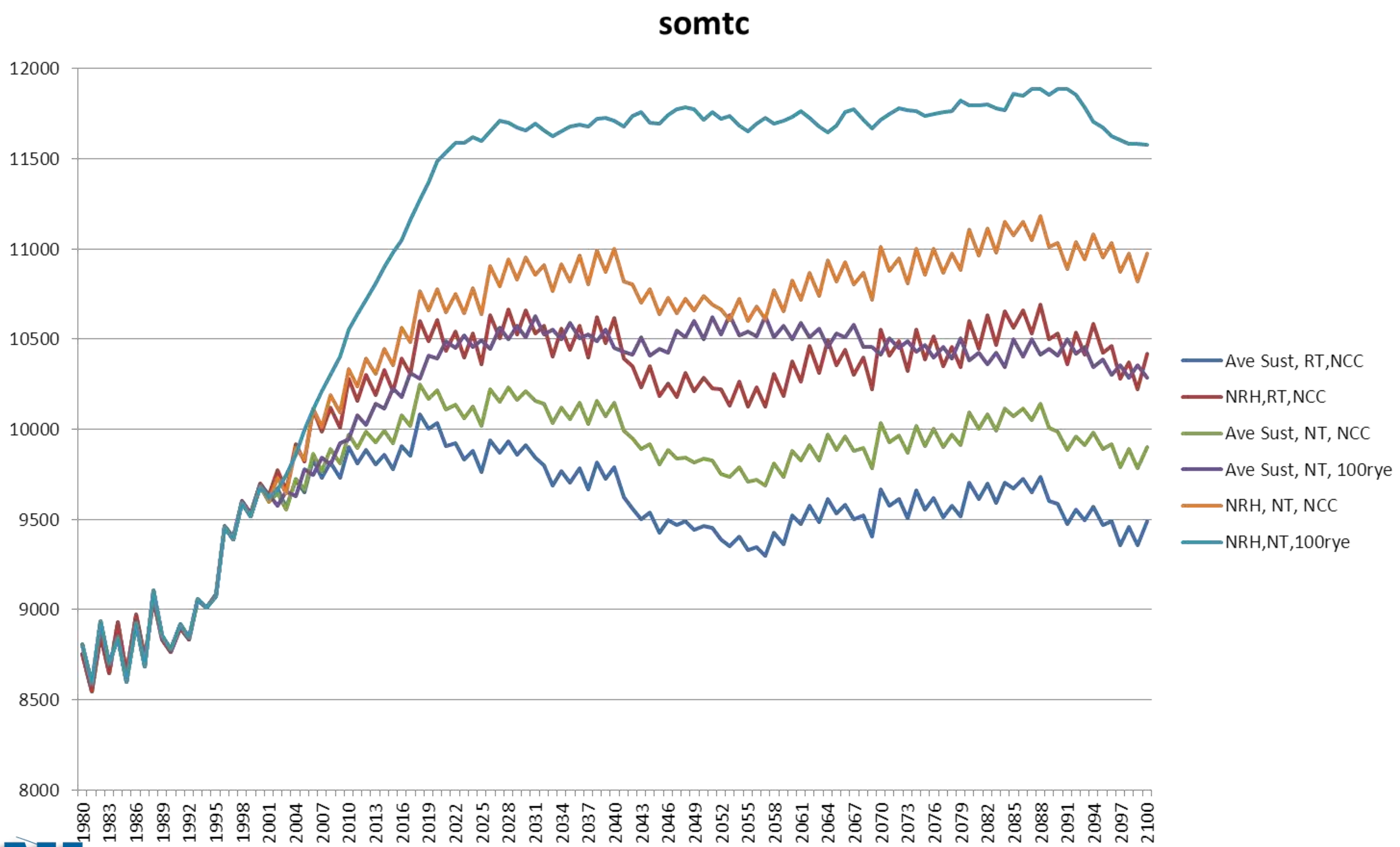
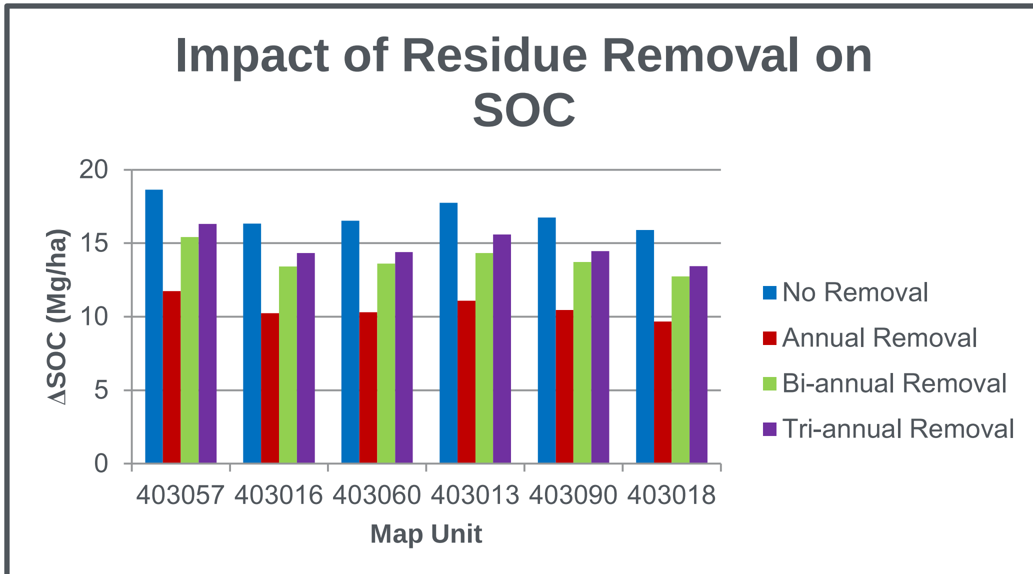
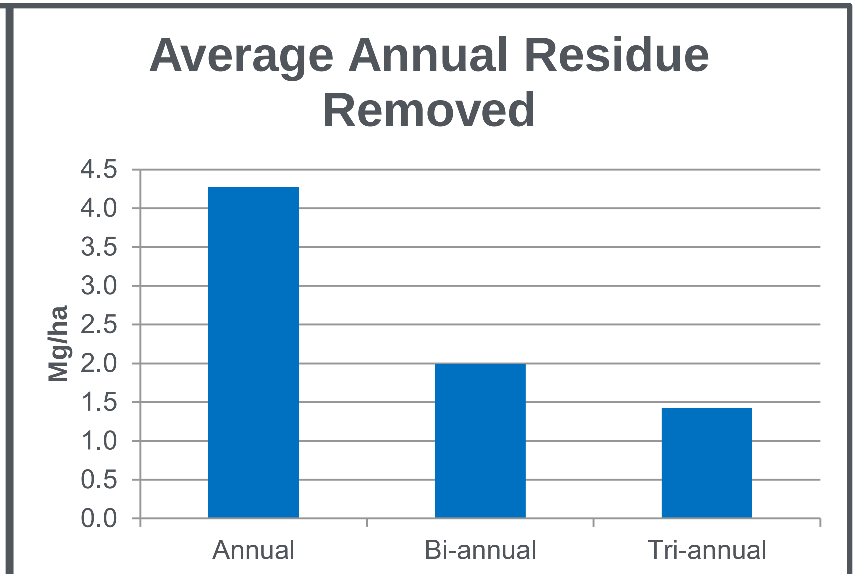
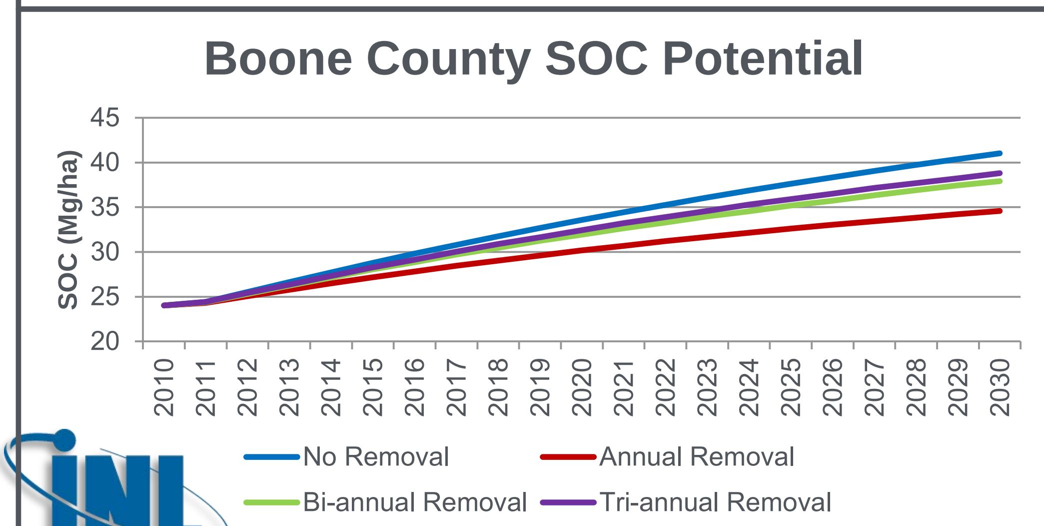
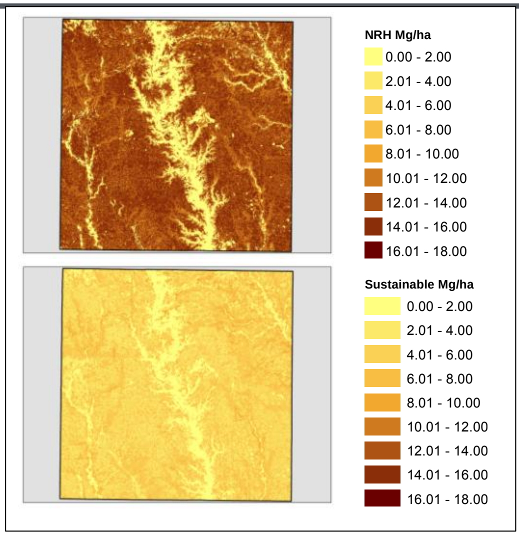


Results


Impact of Residue Removal on SOC
ΔSOC (Mg/ha)
20
15
10
5
0
403057
403016
403060
403013
403090
403018
Map Unit
No Removal
Annual Removal
Bi-annual Removal
Tri-annual Removal


Average Annual Residue Removed
Mg/ha
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Annual
Bi-annual
Tri-annual


Boone County SOC Potential
SOC (Mg/ha)
45
40
35
30
25
20
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
No Removal
Annual Removal
Bi-annual Removal
Tri-annual Removal


NRH Mg/ha
0.00 - 2.00
2.01 - 4.00
4.01 - 6.00
6.01 - 8.00
8.01 - 10.00
10.01 - 12.00
12.01 - 14.00
14.01 - 16.00
16.01 - 18.00
Sustainable Mg/ha
0.00 - 2.00
2.01 - 4.00
4.01 - 6.00
6.01 - 8.00
8.01 - 10.00
10.01 - 12.00
12.01 - 14.00
14.01 - 16.00
16.01 - 18.00

Case Study: 20 Year SOC Impacts

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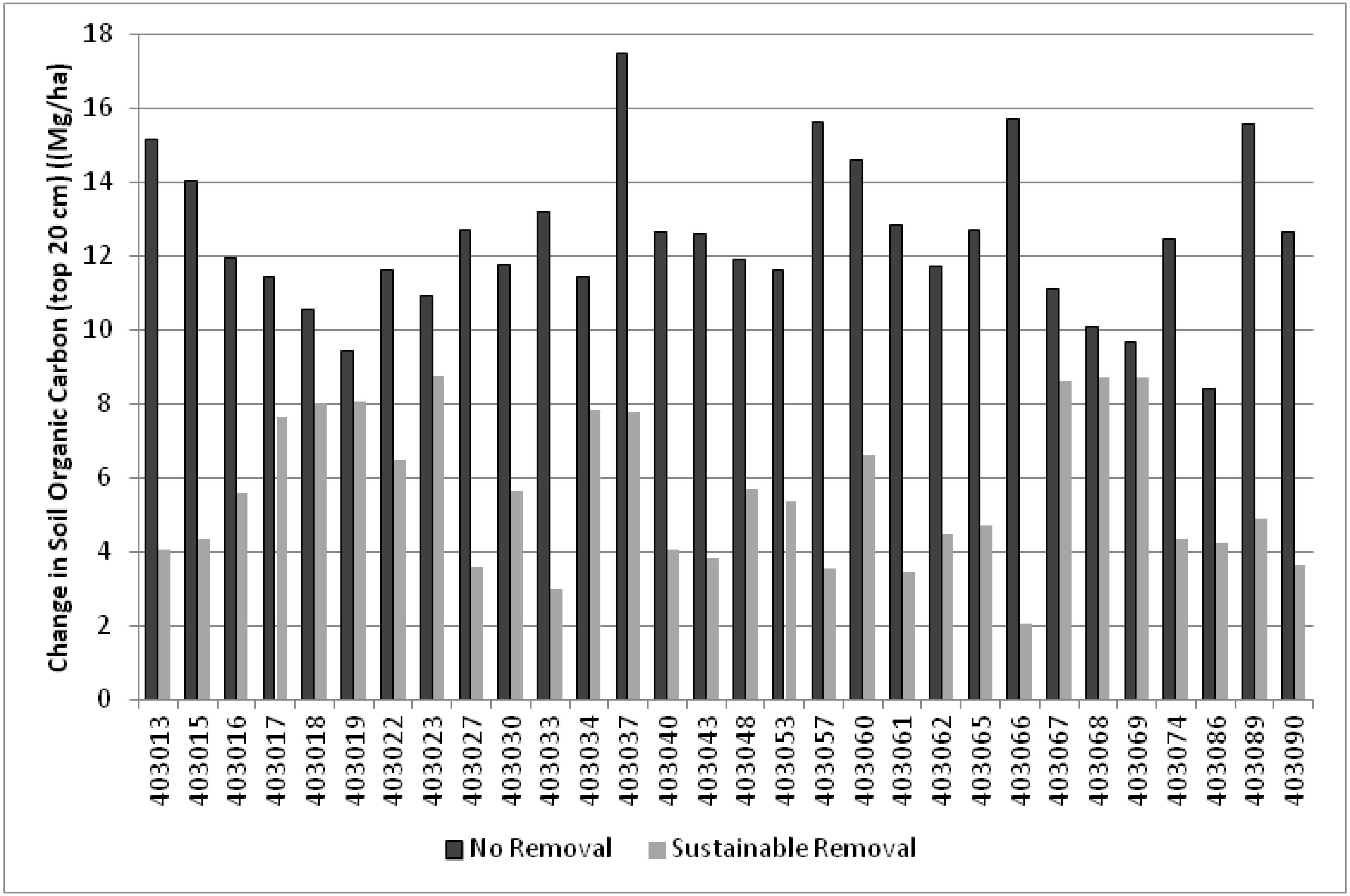

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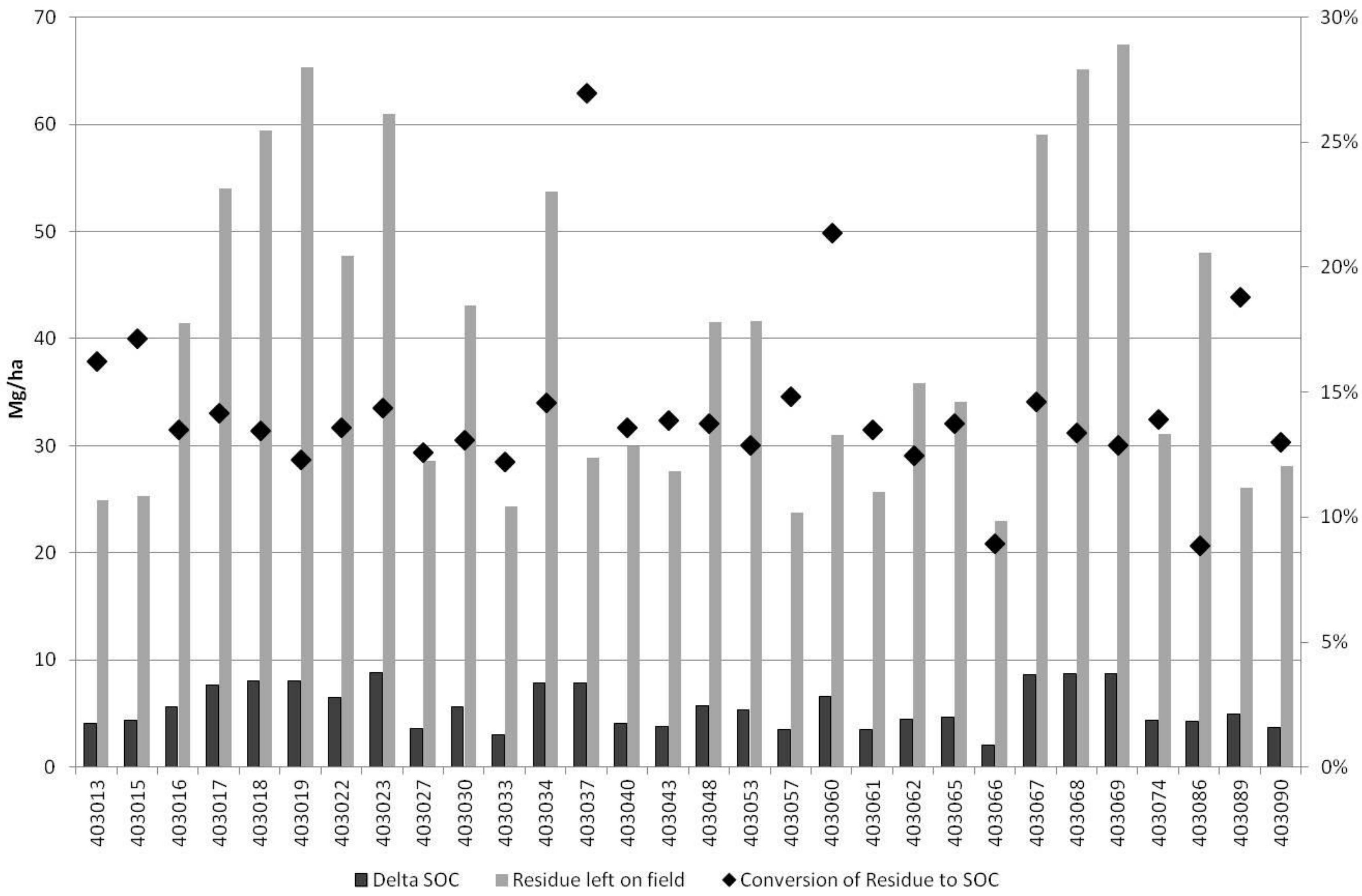
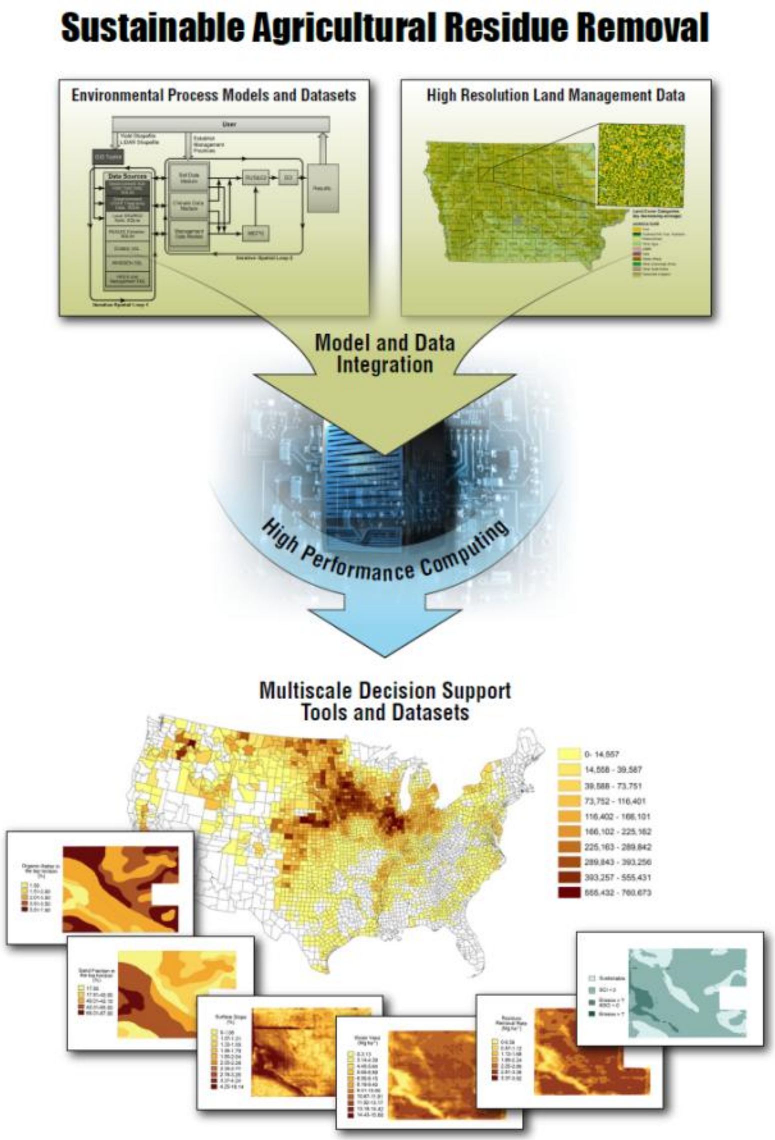
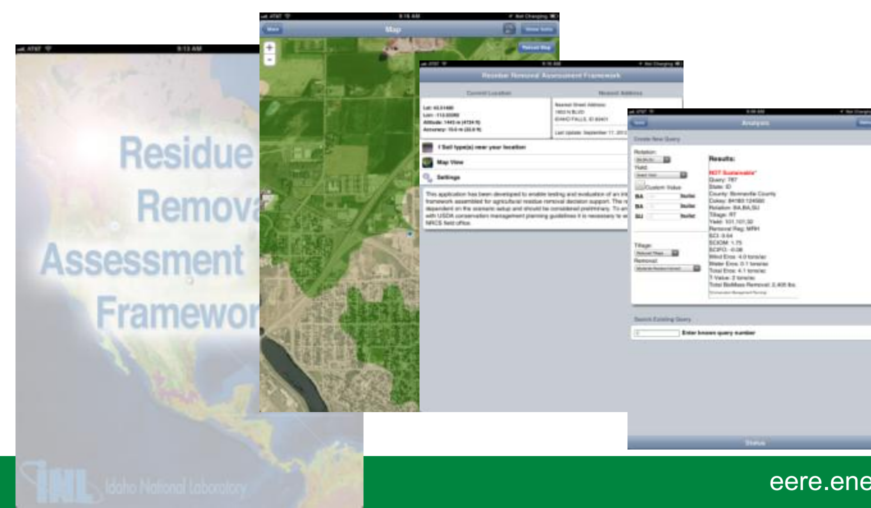


Residue Removal Decision Toolset: Current Deployments

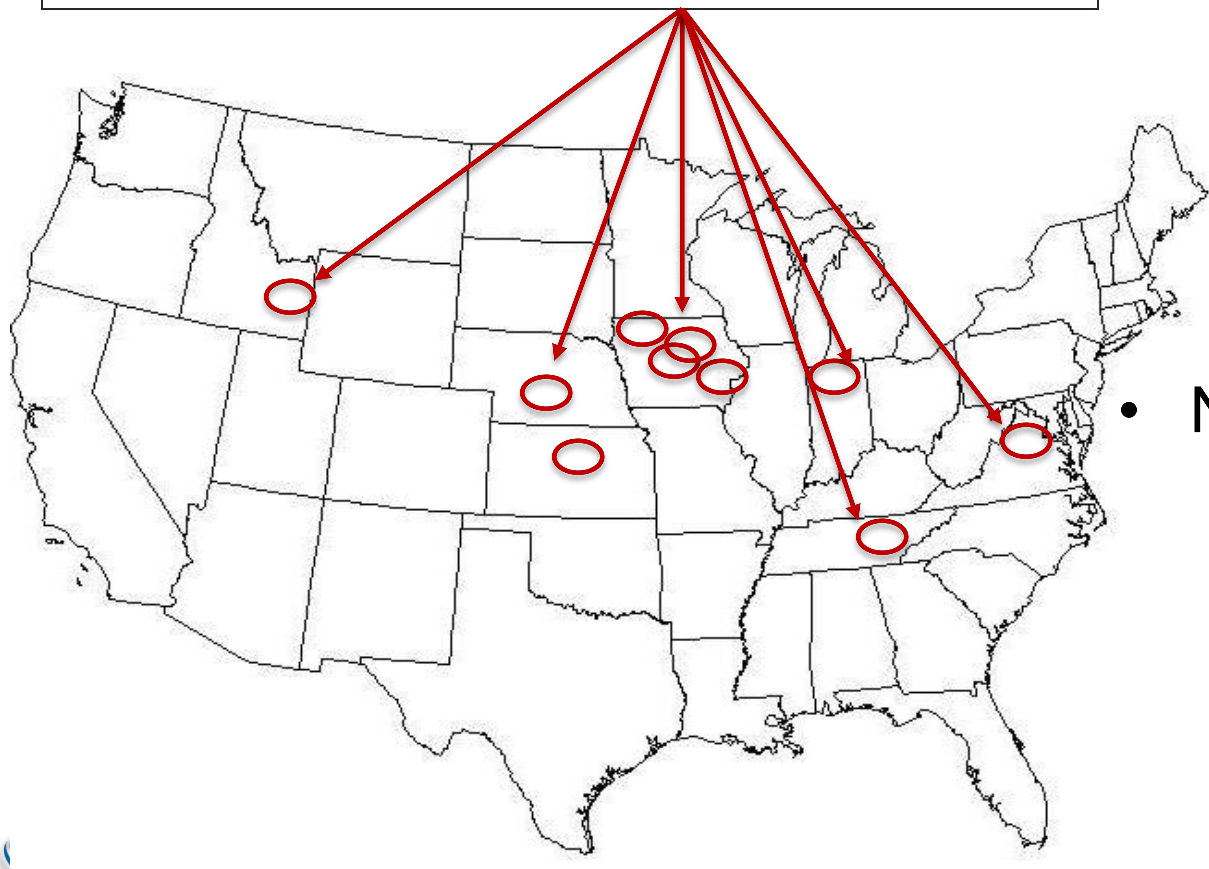


- SustainR2 Mobile App
  - iOS version available in Apple App Store
  - URL: http://bioenergyldt.inl.gov/mobile
- Map Selection Webtool: beta testing on INL network
- Model Integration and Data Management Core Code Libraries
  - Downloadable from google code project LEAF (Landscape Environmental Assessment Framework)



In the Field Now

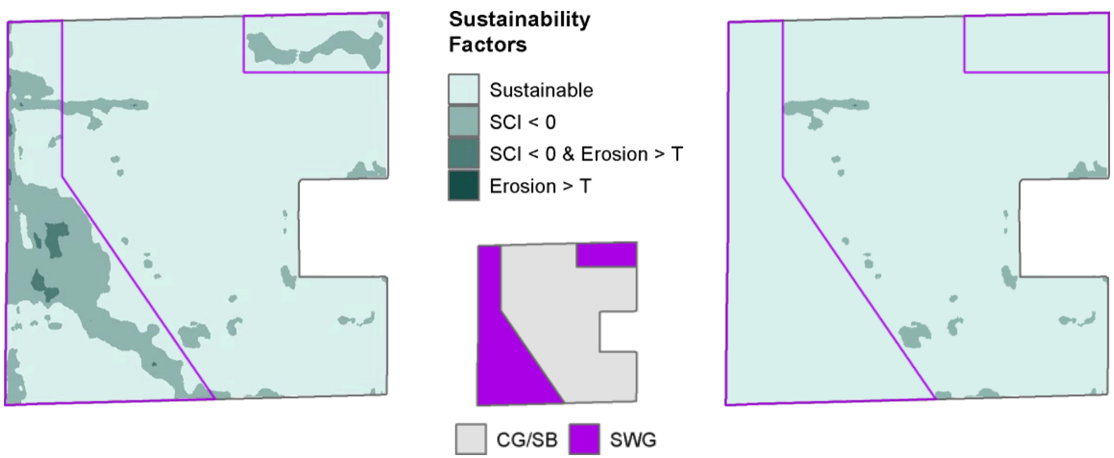
Testing and/or commercial scale locations



- Commercial Users
  - Monsanto
  - DuPont/Pioneer
  - Poet
  - Antares/FDC Enterprises
  - Larksen
- NRCS Test Plan
  - Targeting1-3K use cases this fall
  - Will validate results with NRCS field offices

Agronomic Strategies: Integrated Cropping Systems

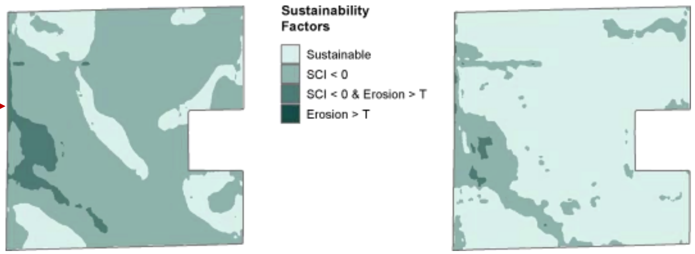
Perennial Switchgrass	
11/1 Year 1	Chisel Plow
4/15 Year 2	Field Cultivation
4/15 Year 2	Plant Switchgrass
12/15 Year 3-8	Harvest Switchgrass



Agronomic Strategies: Integrated Cropping Systems

Rake and Bale Removal	Reduced Tillage		
	Annual Sustainable Residue (metric tons)	Percentage of Field Managed Sustainably	Annual Soil Loss (metric tons)
Scenario 1 (Corn/Soy)	36	21%	316
Scenario 2 (Corn/Rye/Soy)	140	83%	182

Impacts of row crop production management decisions across the whole field.



Agronomic Strategies: Integrated Cropping Systems

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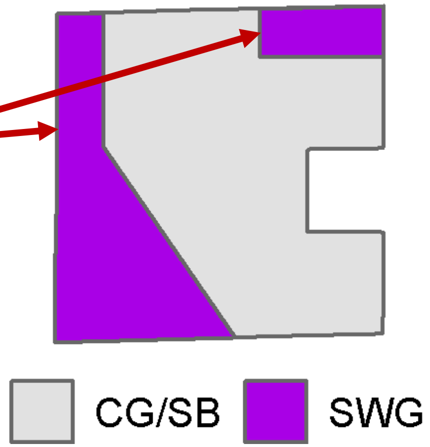
Rake and Bale Removal	**Reduced Tillage**		
	Annual Sustainable Residue (metric tons)	Percentage of Field Managed Sustainably	Annual Soil Loss (metric tons)
Scenario 5 (Switch)	86	100%	11
Scenario 6 (Corn/Soy in Switch area)	10	18%	172
Scenario 7 (Corn/Rye/Soy in Switch area)	33	61%	79

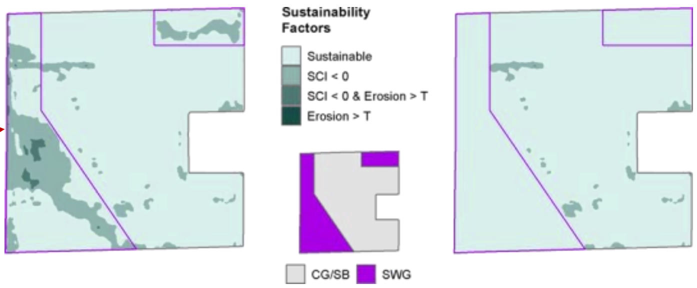
Impacts from management decisions in the "at-risk" areas of the field.



Agronomic Strategies: Integrated Cropping Systems

Rake and Bale Removal	Reduced Tillage		
	Annual Sustainable Residue (metric tons)	Percentage of Field Managed Sustainably	Annual Soil Loss (metric tons)
Scenario 3 (Corn/Soy & Switch)	113	48%	155
Scenario 4 (Corn/Rye/Soy & Switch)	193	96%	114

Impacts from landscape management approach to production decisions.



Agronomic Strategies: Integrated Cropping Systems

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