Farm Landscape Design Decision Support

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Landscape Design Project meeting

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Idaho National Laboratory

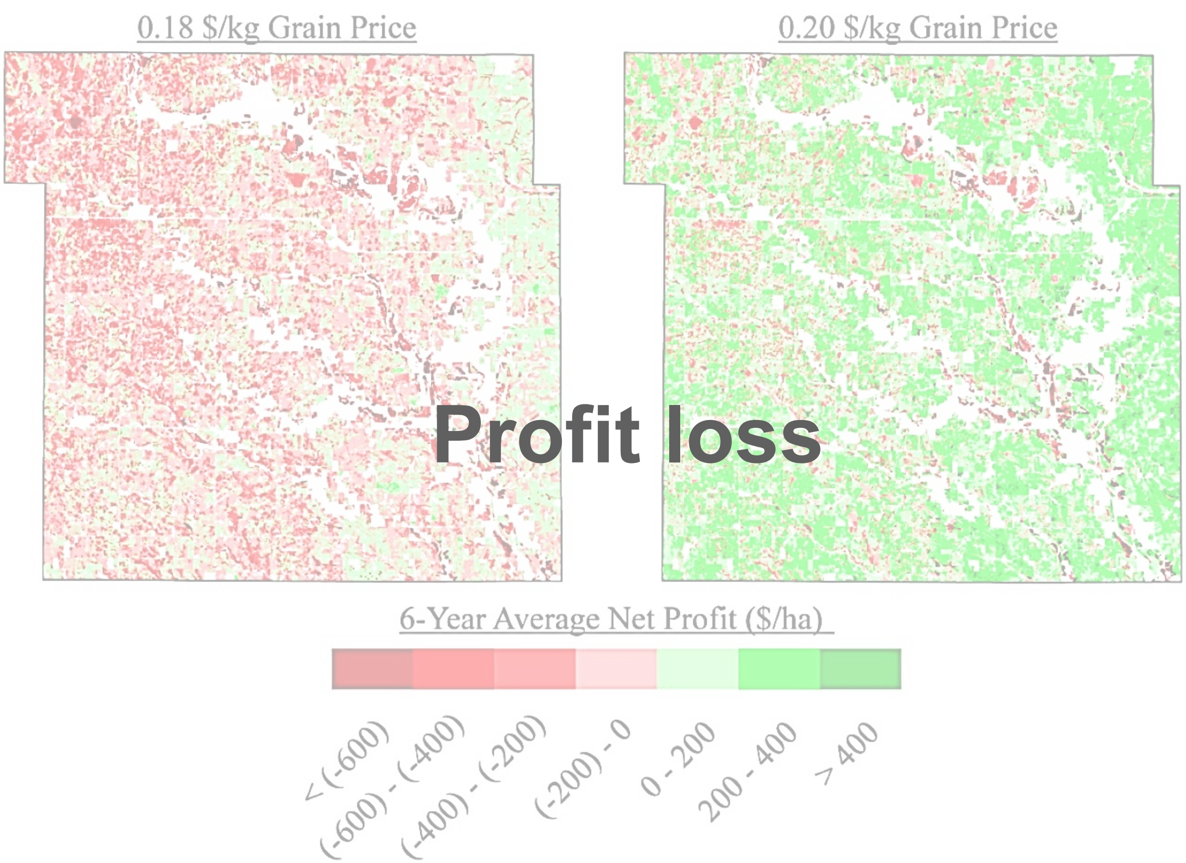
Research motivation and goal

Support farmer decisions for sustainable landscape designs to meet their priorities using:

- Stakeholder engagement
- Sustainability assessment
- Spatial analysis and optimization

The problem

- Current agricultural **field configurations** (placing annual crop on the entire fields) lead to economic loss and environmental degradation

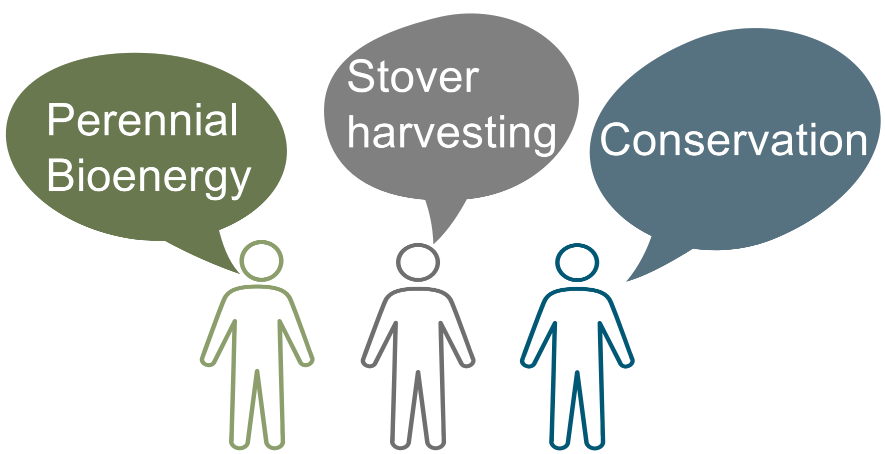


(Bonner et.al. 2014)

Erosion

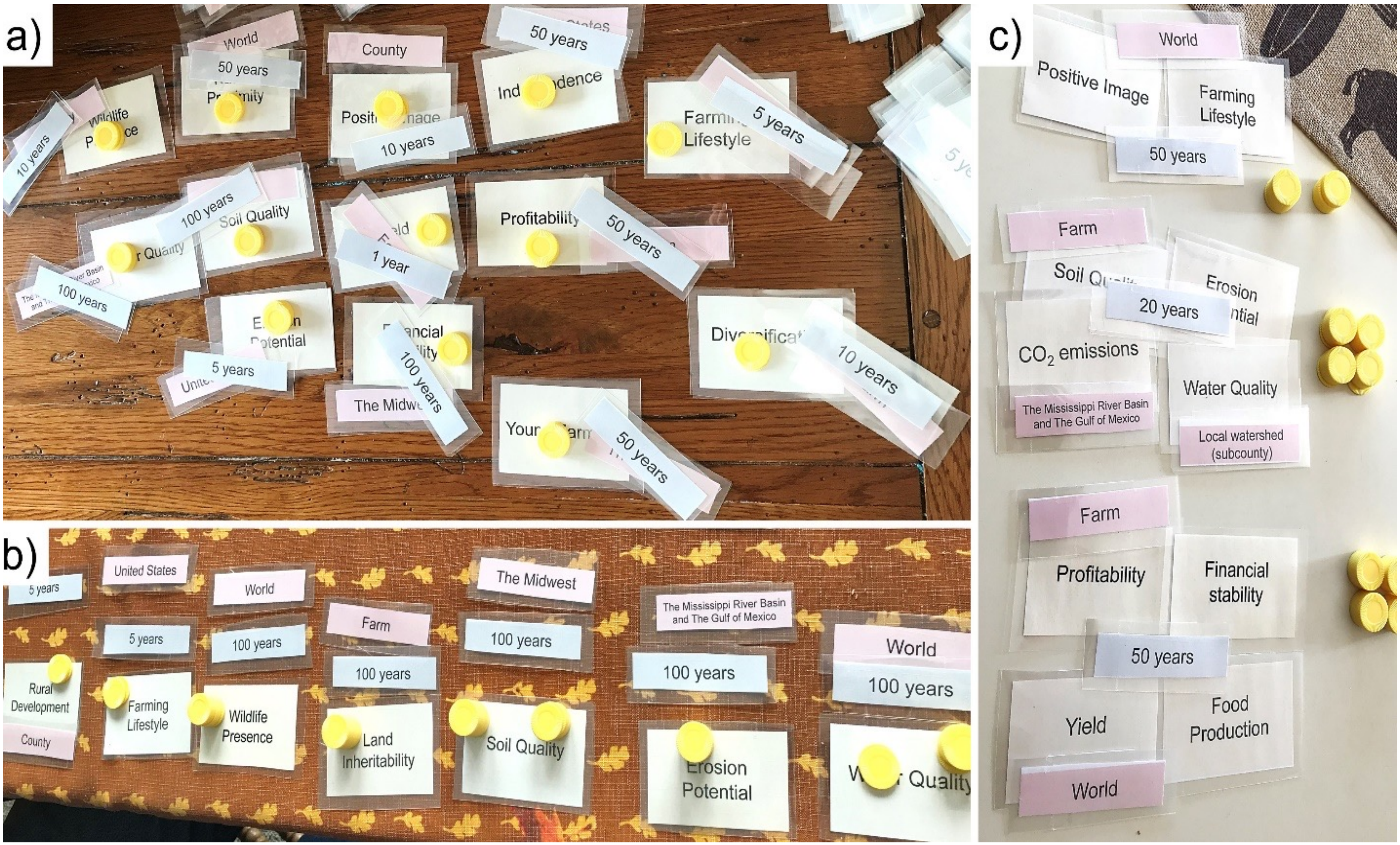
Eutrophication

Optimization inputs – expert elicitation

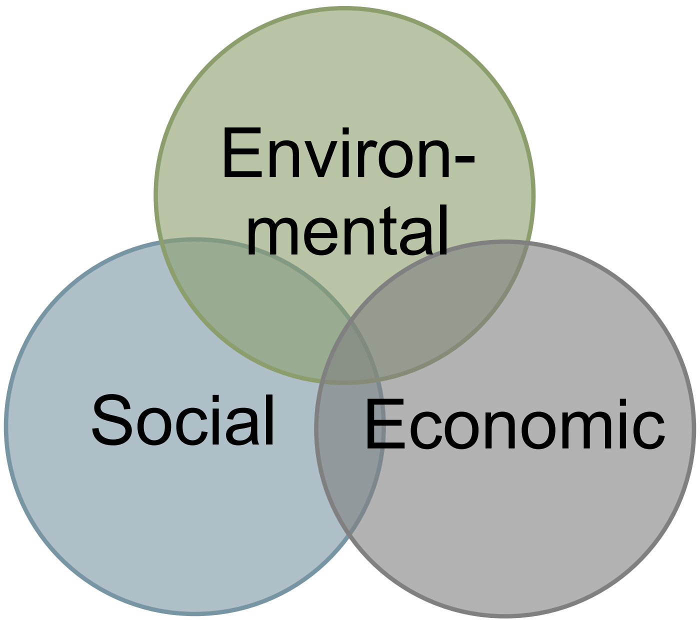


- Farmer interviews, February 2019
  - 37 interviews (46 farmers) across Iowa
  - 18 key priorities across groups used for the analysis
- Follow-up interviews, November 2019
  - 15 interviews
  - Review of indicators, time and space considerations

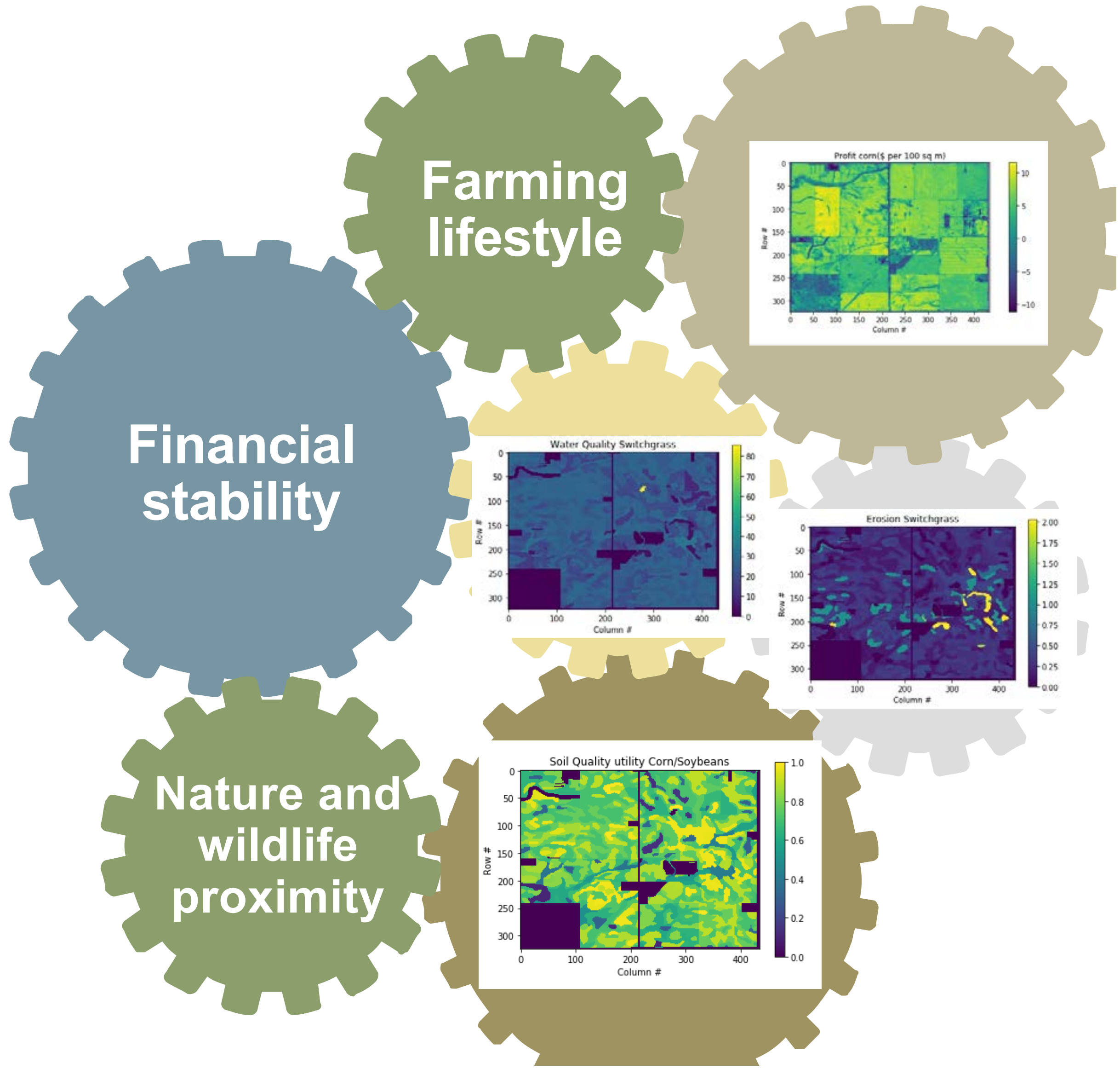
Priorities


a)
World
50 years
County
50 years
Wildlife
10 years
10 years
Farming Lifestyle
5 years
100 years
Soil Quality
1 year
Profitability
50 years
100 years
5 years
100 years
The Midwest
Your Farm
50 years
10 years
b)
5 years
United States
World
The Midwest
Farm
The Mississippi River Basin and The Gulf of Mexico
World
5 years
100 years
100 years
100 years
100 years
100 years
Rural Development
County
Farming Lifestyle
Wildlife Presence
Land Inheritability
Soil Quality
Erosion Potential
c)
World
Positive Image
Farming Lifestyle
50 years
Farm
20 years
CO2 emissions
Water Quality
The Mississippi River Basin and The Gulf of Mexico
Local watershed (subcounty)
Farm
Profitability
Financial stability
50 years
Yield
Food Production
World

Indicator measures for optimization



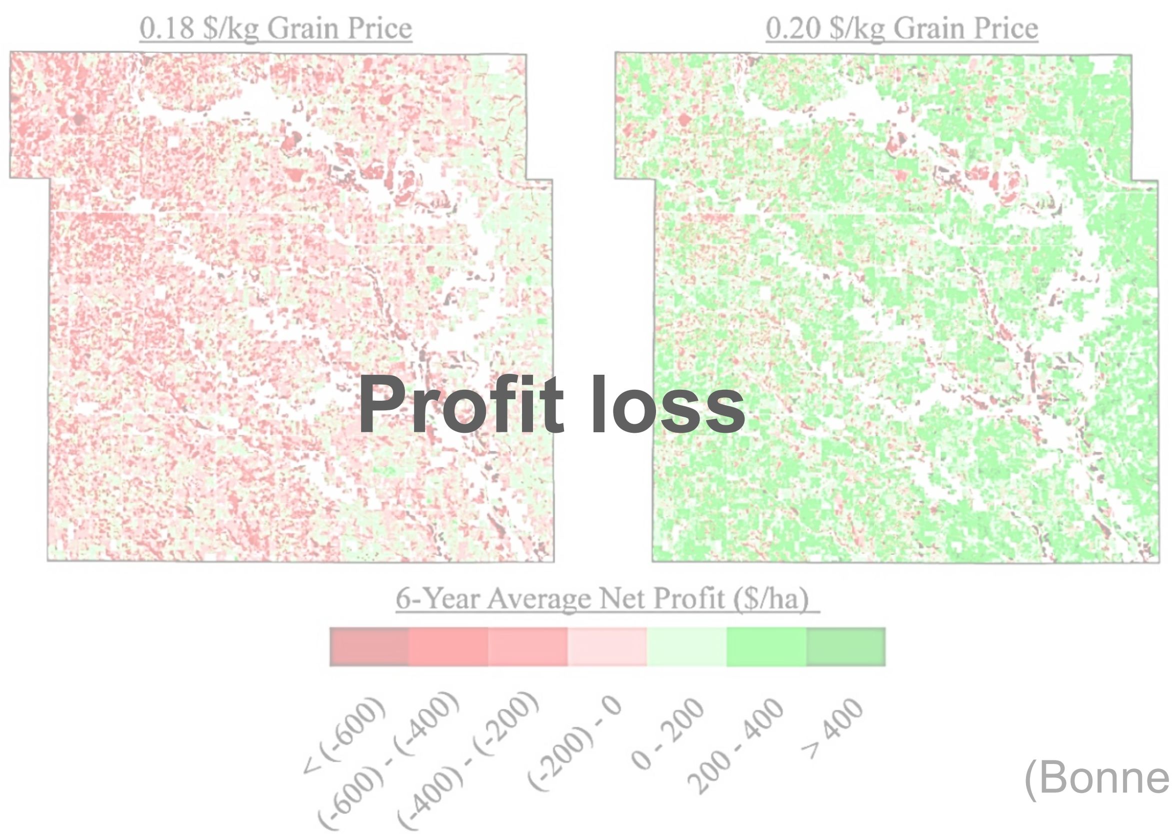
Sustainability pillars



Connected indicators

Addressing the 'Profitability' priority

- Stakeholder interviews point to **profitability** as one of the top producer priorities
- Can perennial grasses make an **economic case** on productive Iowa land?



(Bonner et.al. 2014)

Profitability assessment

Imagery

Sentinel-2A

Landsat 8

Processing

Google Earth Engine

1. Calculate peak NDVI and convert into yield

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

$$Yield = Coefficient \times e^{3.3525 \times NDVI}$$

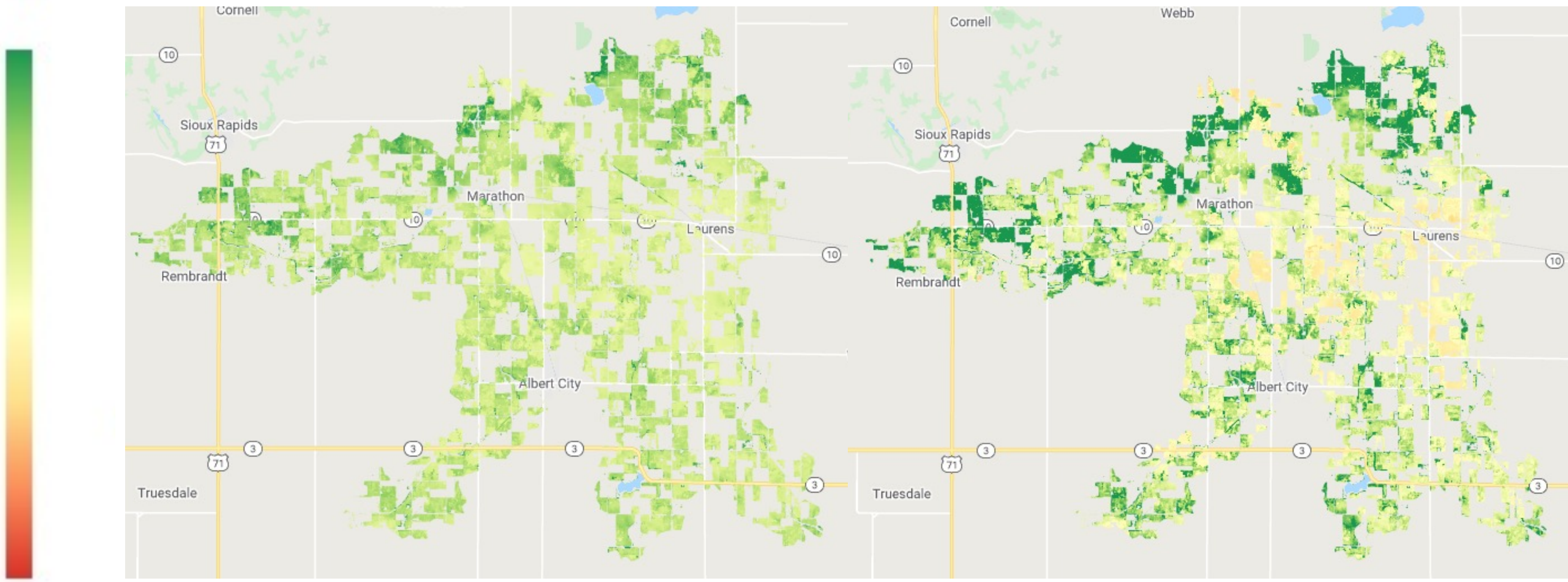
(Teal et al. 2006)

2. Calculate profit based on crop budgets

Yield variability for switchgrass and maize

Yield

14 Mg/ha



0 Mg/ha

Switchgrass variability **Corn variability**

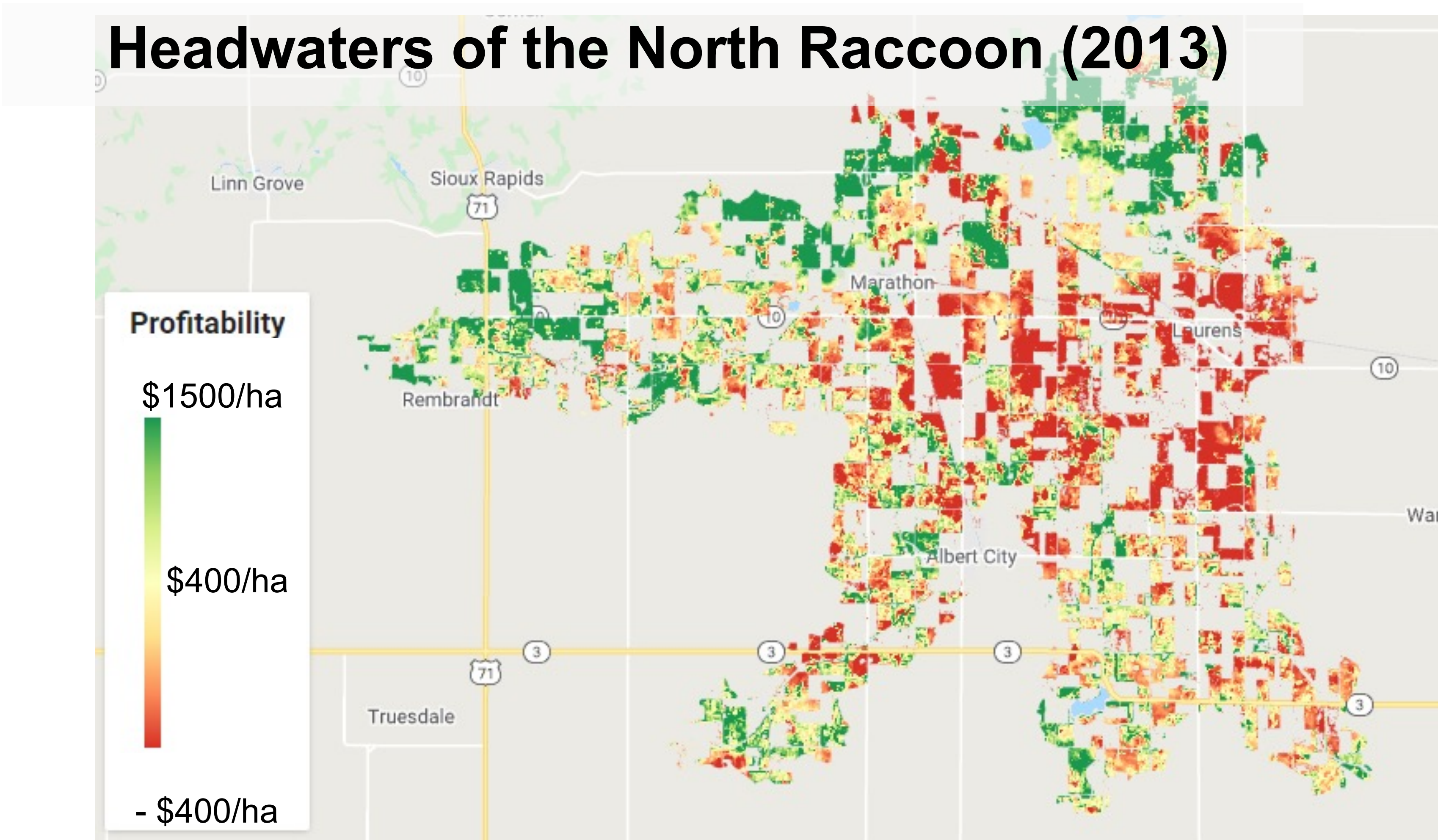
Profitability calculation

$$Profit_{corn} = \left(Y_{grain} \times P_{grain} - C_{grain}\right) + (Y_{stover} \times P_{biomass} - C_{stover}) + Grain\ Subsidy - Land\ Rent$$

$$Profit_{switchgrass} = (Y_{switchgrass} \times P_{biomass} - C_{grain}) - Land\ Rent$$

$$P_{biomass} = \begin{cases} 50, & Low\ value\ market\ scenario\ (\frac{\$}{Mg}) \\ 100, & Average\ value\ market\ scenario\ (\frac{\$}{Mg}) \\ 150, & High\ value\ market\ scenario\ (\frac{\$}{Mg}) \end{cases}$$

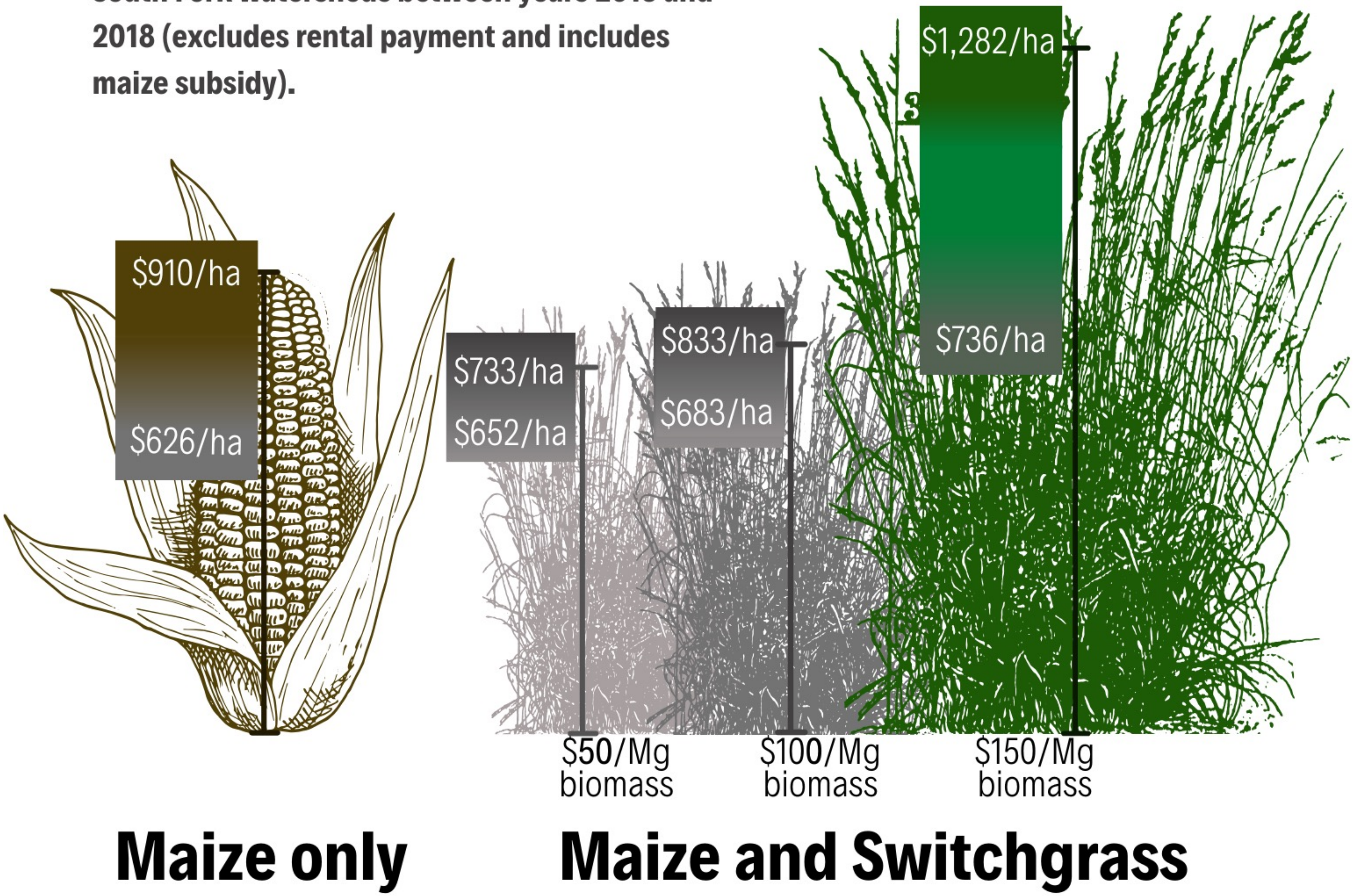
Profitability results



Example run of maize profitability analysis for 2013 (grain with stover harvest at $150/Mg price scenario, without adding switchgrass) including land rent and with grain subsidy

Average profitability
(among harvest scenarios and years)

Profitability on the fields in North Raccoon and South Fork watersheds between years 2013 and 2018 (excludes rental payment and includes maize subsidy).



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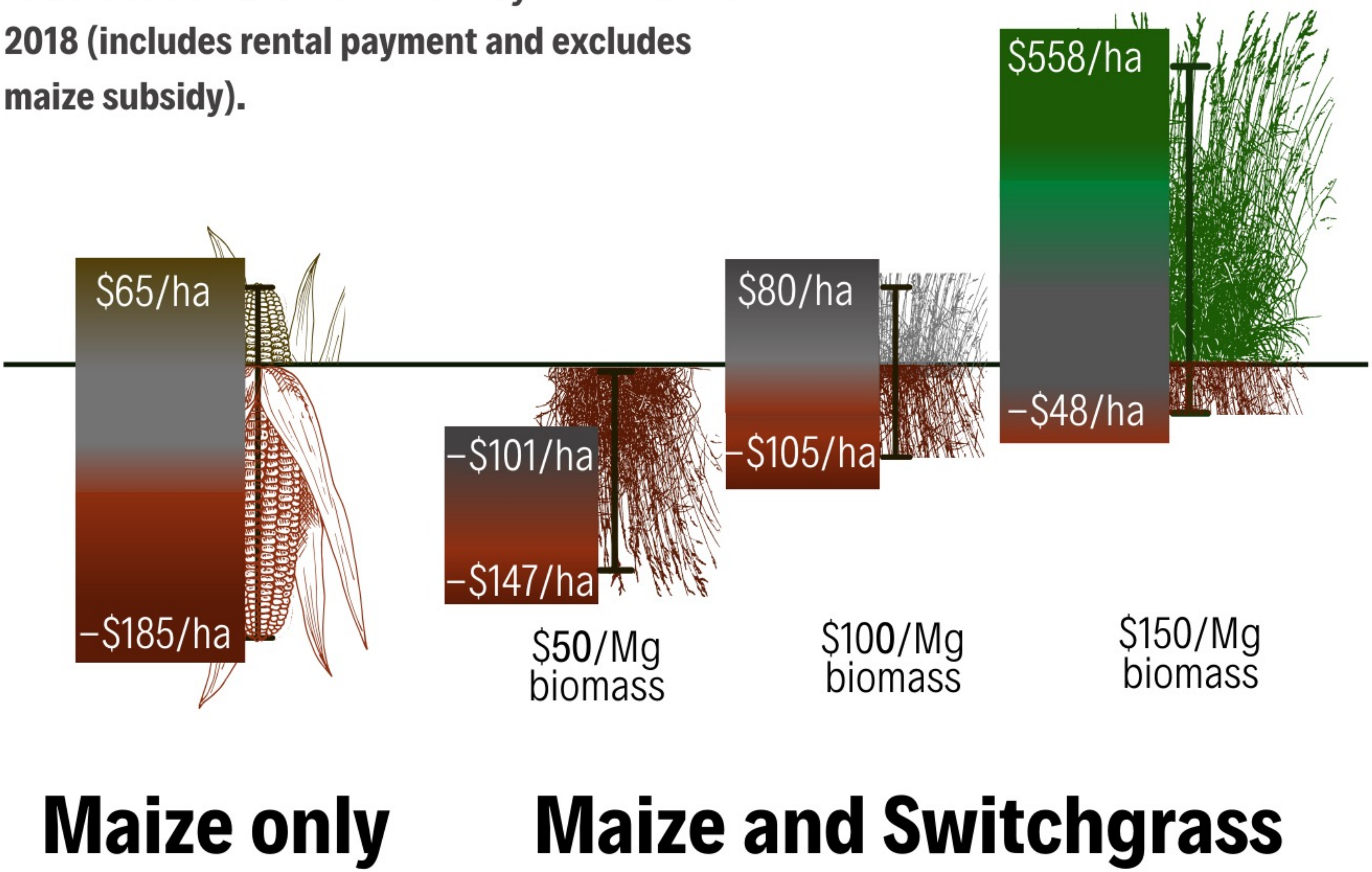


Note: The reason that the highest average of the maize profit is higher than for the integrated case is because in that case, the stover biomass price was set at $150/Mg; while in the $50/Mg integrated case, all biomass price is at $50/Mg.

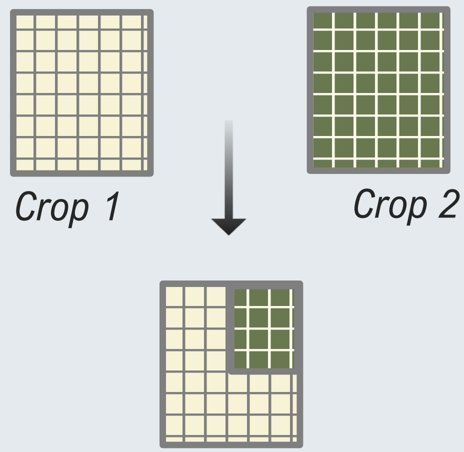
Spatial analysis framework

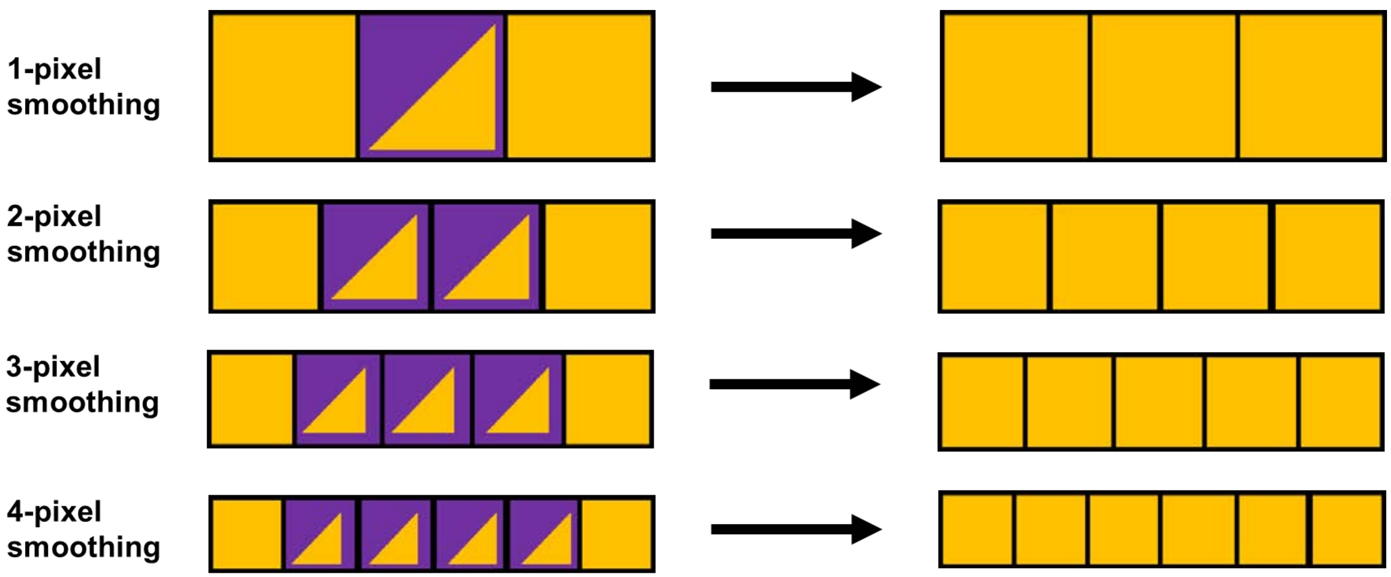
- Subfield-level detail of analysis
  - **Stakeholder**-informed decision variables
  - **Sustainability** assessment
  - **Utility** values to represent sustainability indicators
  - **Spatial** suitability assessment using bit-wise comparison and optimization

Spatial data processing

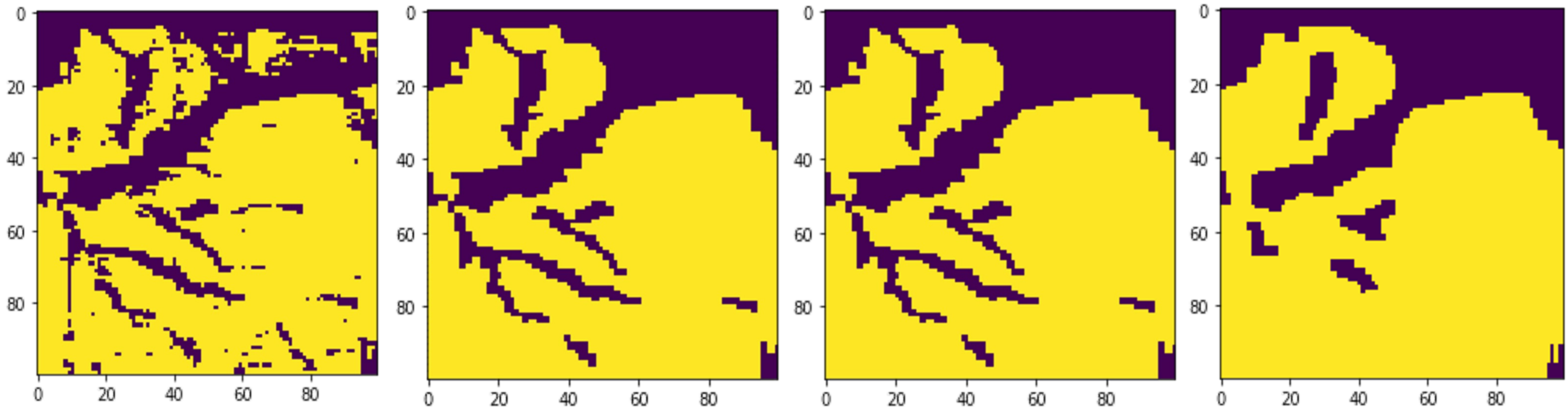
Farm boundaries

Bit-wise comparison:





Smoothing



Pixel-by-pixel comparison	1-pixel smoothing	2-pixel smoothing	3-pixel smoothing
90 **subfields**	x10 fewer subfields	x10 fewer subfields	x11.25 fewer subfields
39% **field efficiency**	+51.8% efficiency increase	+52.3% efficiency increase	+56.9% efficiency increase

Field efficiency calculations based on (Griffel et al. 2020)

Crop suitability maps (2-pixel smoothing)

Weight

Financial stability– 0.5

Profitability – 0.25

Yield – 0.25

Profitability – 0.42

Yield – 0.21

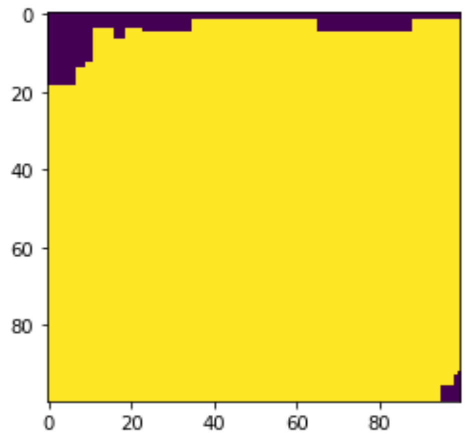
Soil quality – 0.11

Erosion potential – 0.11

Water quality – 0.05

Positive image – 0.05

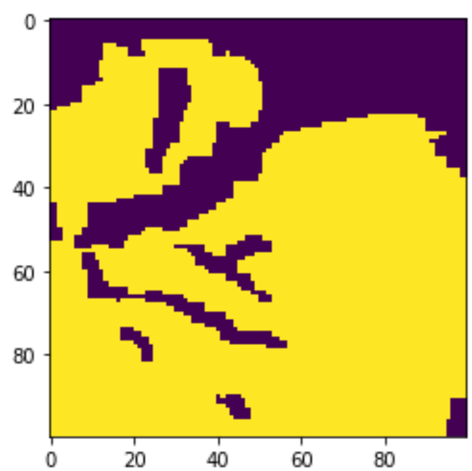
Inheritability – 0.05



Total utility: 5676

Subfields: 3

Field efficiency: 70%



Total utility: 4163

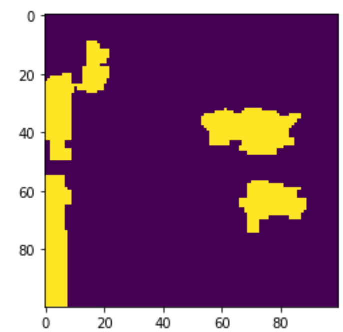
Subfields: 9

Field efficiency: 59.4%

Crop suitability maps (2-pixel smoothing)

Weight

- Profitability – 0.15
- Soil quality – 0.15
- Diversification – 0.11
- Inheritability – 0.09
- Independence - 0.08
- Financial stability – 0.08
- Water quality – 0.08
- Erosion potential – 0.08
- Food production – 0.08
- Yield – 0.06
- Wildlife – 0.05

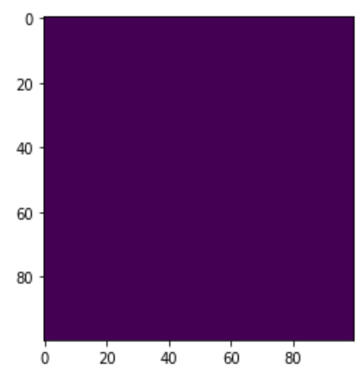


Total utility: 4605

Subfields: 5

Field efficiency: 87.1%

All indicators - equal



Total utility: 5117

Subfields: 1

Field efficiency: 98%

Key contributions and future work

Farm landscape decision support framework

- Understand the diversity of priorities and spatial and temporal boundaries of concern
- Illustrate agricultural producer-relevant sustainability indicators
- Map where switchgrass can be more economically feasible than annual crops
- Readily usable crop allocation landscape design based on spatial analysis

Acknowledgements

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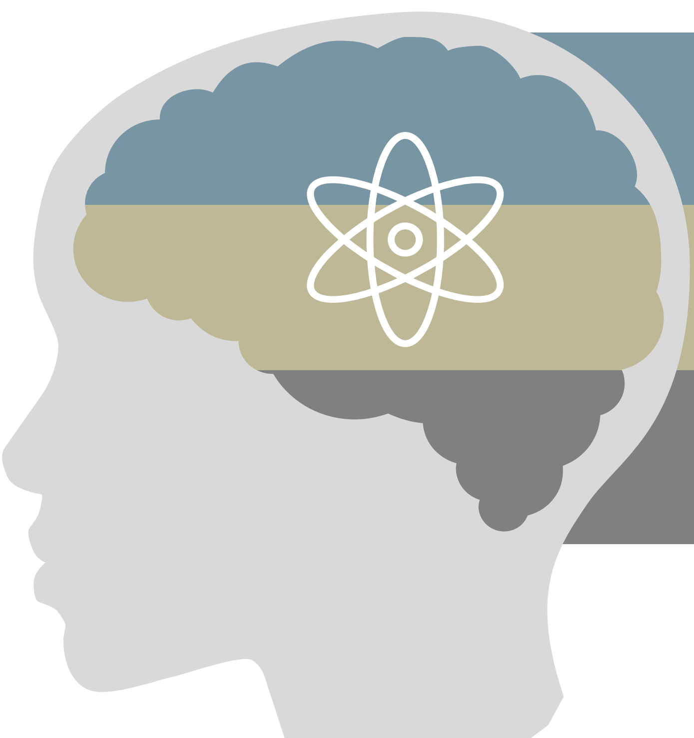
Additional slides

Priorities



Profitability
36/37 interviews. Weight between **16** and **27**%

Water quality
30/37 interviews. Weight between **6** and **12**%

Soil quality
29/37 interviews. Weight between **7** and **12**%

Soil erosion
28/37 interviews. Weight between **4** and **13**%

Wildlife and nature proximity
28/37 interviews. Weight between **3** and **6**%

Priorities

Independence
29/37 interviews. Weight between **2** and **3**%

Good image of practices
19/37 interviews. Weight between **0** and **2**%

Opportunities for young farmers
19/37 interviews. Weight between **2** and **8**%

Rural development
11/37 interviews. Weight **0** and **2**%

Lifestyle
7/37 interviews. Weight between **3** and **10**%

Corn stover harvest

- $Y_{stover} = 0.714 \times Y_{grain} - 5$

Wilhelm et al. (2007)

- $Y_{stover} = 0.61 \times Y_{grain} + 2.4 - Min. Stover\ Remain$

Tan and Liu (2015) ; Johnson et al. 2016

- Harvesting cost at $100/Mg

Thompson and Tyner (2014)