MORE THAN BIOMASS: PURPOSEFULLY GROWN FOR ECOSYSTEM SERVICES

Continuing CAAFI webinar series

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ABOUT ARGONNE'S ENVIRONMENTAL SCIENCE DIVISION

COMPUTING, ENVIRONMENT AND LIFE SCIENCES DIRECTORATE

EARTH SYSTEMS

We advocate Earth systems science and climate science, and we improve our understanding of climate risk and resiliency and better understand the effects of climate risks on natural and managed systems, energy availability, human livelihood, and biodiversity.

ENERGY AND ENVIRONMENTAL IMPACTS

We understand and predict the interactions between energy systems and other human activities and ecosystems. We also provide science-based solutions to mitigate unwanted impacts.

RESPONSIBLE INNOVATION

We drive new discoveries and use of natural resources toward responsible outcomes. We embed our scientific knowledge of environmental systems into the design of new materials and processes to preempt unwanted impacts on the environment and to improve our natural capital.

ASKING DIFFERENT KINDS OF QUESTIONS

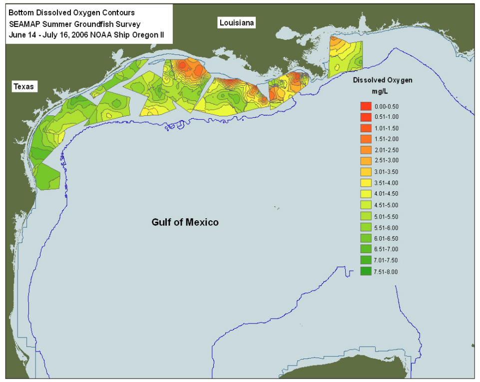
Responsible innovation: **“taking care of the future through collective stewardship of science and innovation in the present”***

Don’t ask what the impacts will be , but design from the start for the enhancement of our natural capital and human wellbeing.

*Stilgoe, Owen, and MacNaghten. https://spectrum.ieee.org/tech-talk/at-work/innovation/what-does-responsible-innovation-mean

AGRICULTURE'S SUSTAINABILITY CHALLENGE

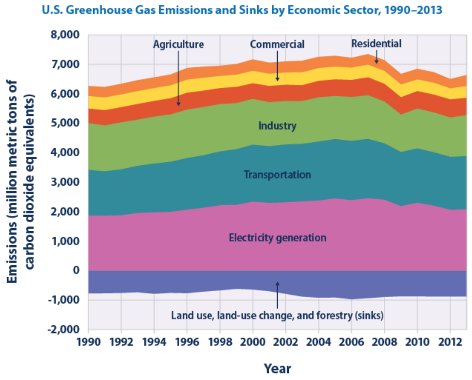
- Providing food, feed, fiber, and energy for a growing world population
- Conserving soil, water and biodiversity, and decreasing greenhouse gases
- Providing resilience to a changing climate
- The rural-urban tension, urbanization and the loss of soil and land



Source: U.S. Global Change Research Program
http://e360.yale.edu/feature
report_gives_sobering_view_of_warmings_impact_on_us/2166/

E. Detaille, Charge of the 4th Hussars at the battle of Friedland, 14 June 1807 - http://upload.wikimedia.org/wikipedia/commons/1/10 Detaille_4th_French_hussar_at_Friedland.jpg

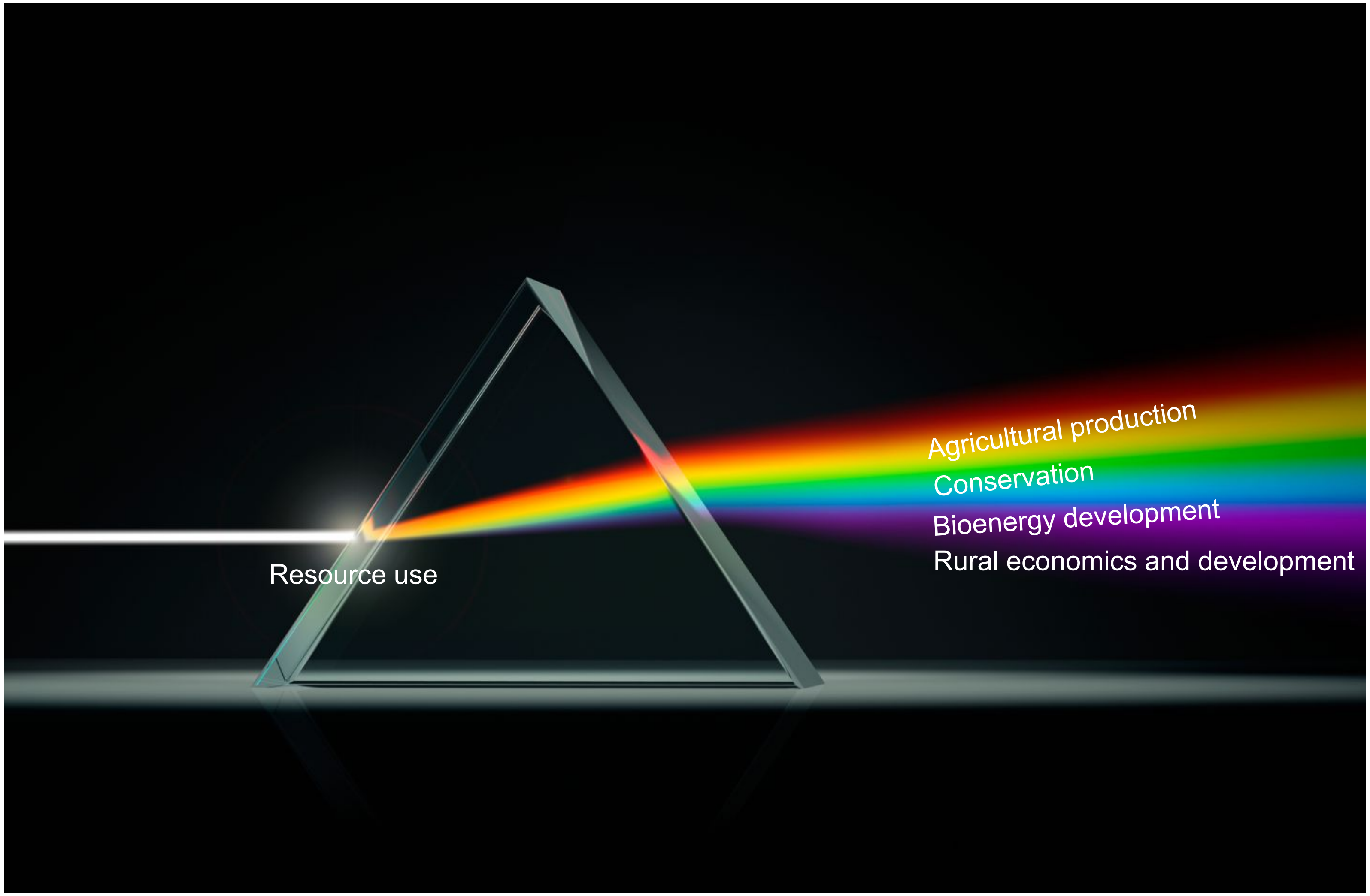
Seeding Our Future by R. L. Crouse.

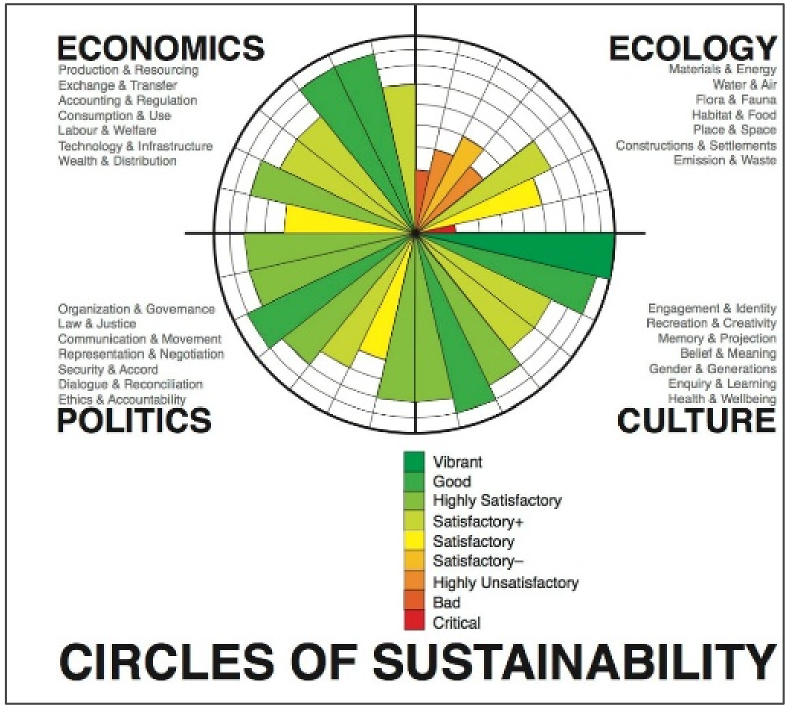


Data source: U.S. EPA (U.S. Environmental Protection Agency). 2015. Inventory of U.S. greenhouse gas emissions and sinks: 1990–2013. EPA 430-R-15-004. www.epa.gov/climatechange/ghgemissions/usinventoryreport.html.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climatechange/indicators.

SYSTEMS LEVEL PROBLEMS DEMAND MULTIPLE OUTCOMES





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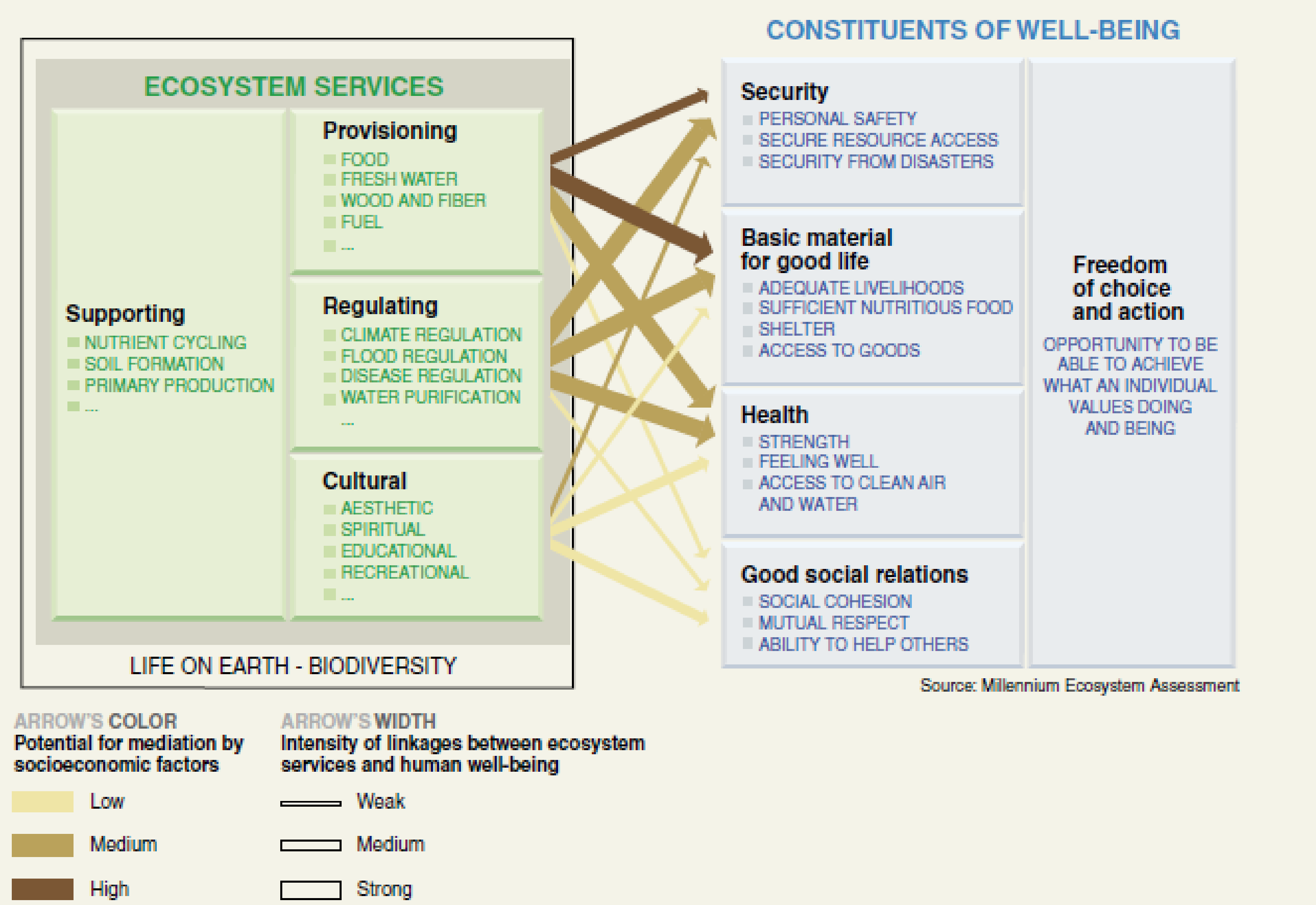
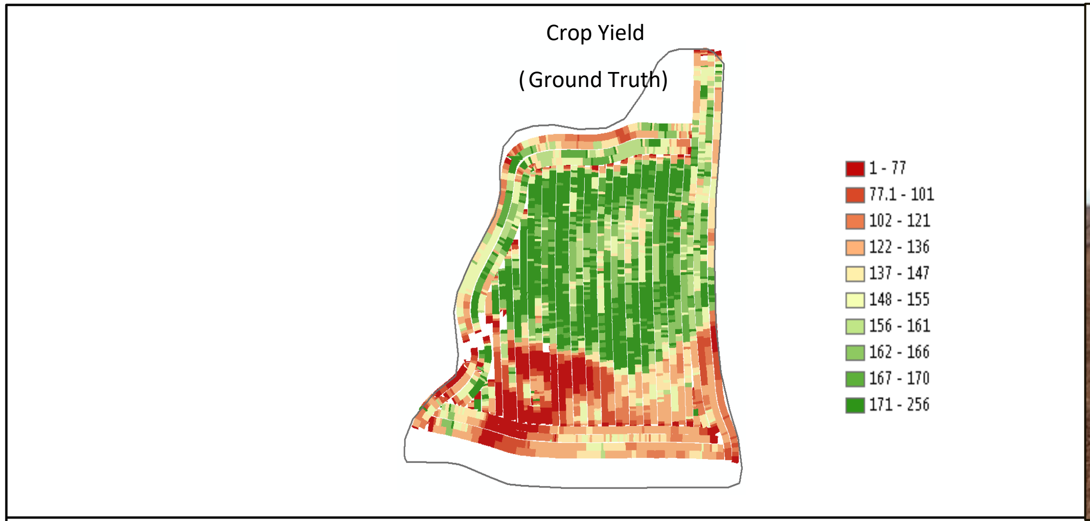
ECOSYSTEM SERVICES THE BENEFITS RECEIVED BY PEOPLE FROM ECOSYSTEMS

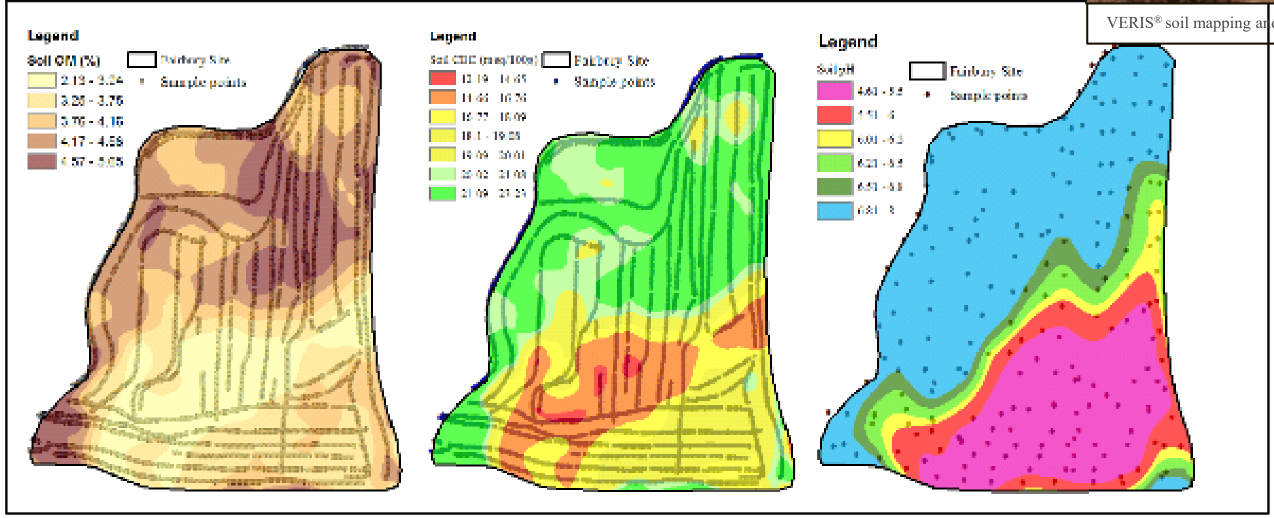


(Millennium Ecosystem Assessment, 2005)

RETHINKING THE AGRICULTURAL LANDSCAPE

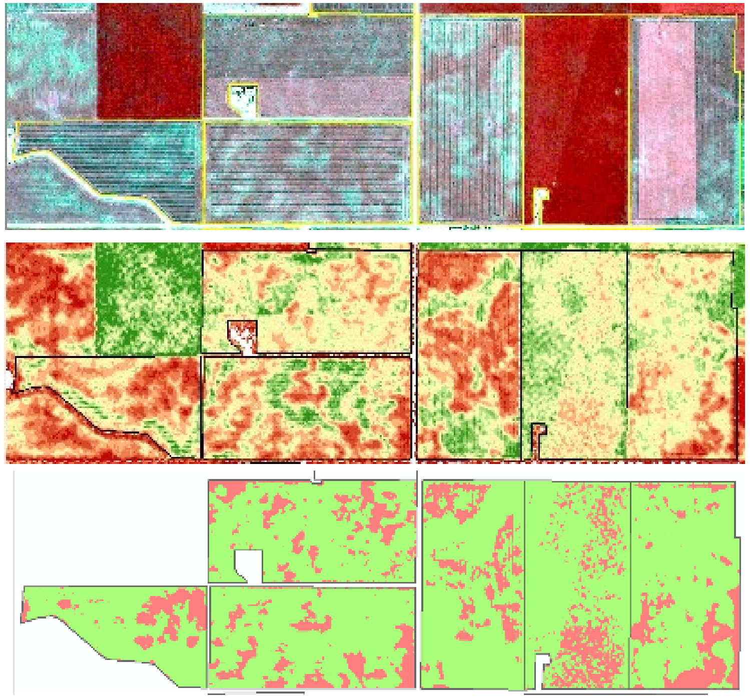
WHAT HAS CHANGED IN AGRICULTURE IN THE LAST DECADES? …..DATA AND GEOSPATIAL SCIENCE AND TECHNOLOGY





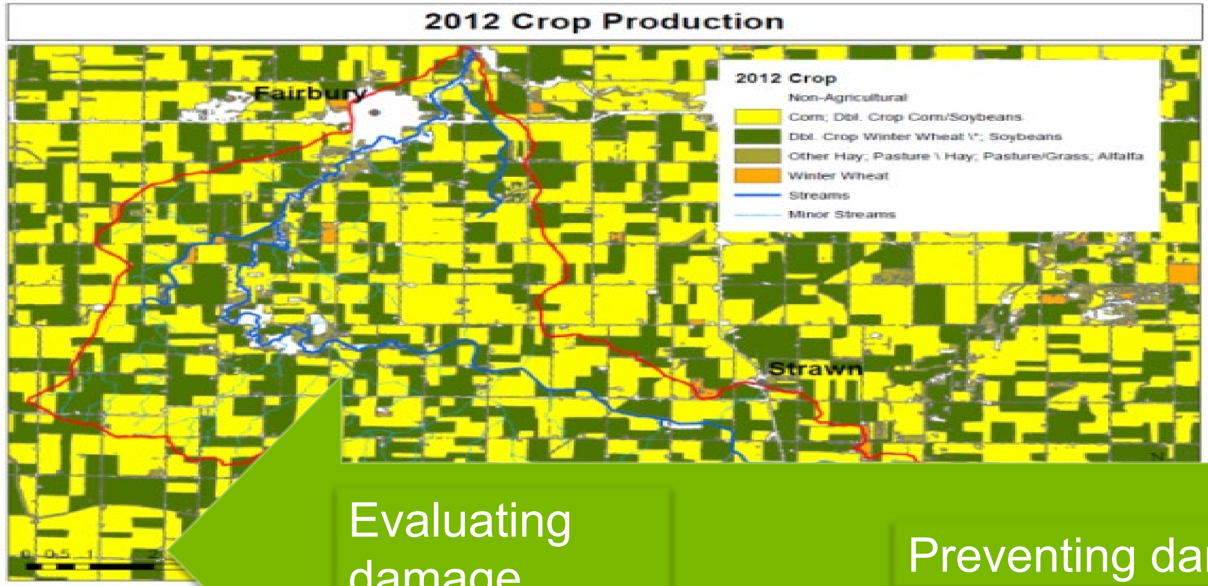
VERIS® soil mapping and image provided by Farm Map Solutions, LLC.

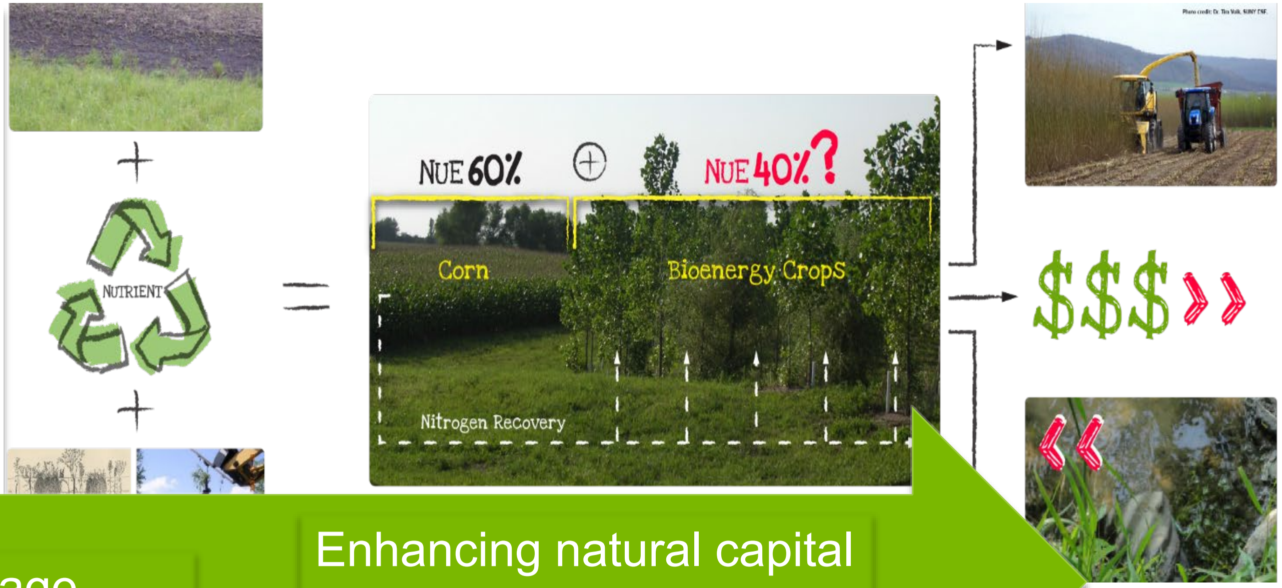
https://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0ahUKEwjOkp-pzbnOAhVC6WMKHUenAysQjB0IBg&url=http%3A%2F%2Fwww.cityofslt.us%2Findex.aspx%3FNID%3D859&psig=AFQjCNFyO0Bb_ruti00SIHBy_xogs6R0DQ&ust=1471013153996332



Hamada et al. (2016)

BIOENERGY LANDSCAPE DESIGN VS. BUSINESS AS USUAL





Evaluating damage — Preventing damage — Enhancing natural capital and human wellbeing

- BAU focused on providing:
  - One *provisioning* service: yields, profit.
  - *Regulating* services not factored in the economics, called externalities
  - Conceptual focus is how to mitigate the impacts retroactively
  - Non diversified business models concentrates risk

Landscape Design focused on providing:
  - *Provisioning services* – optimize yields of food, feed, fiber, bioenergy, bioproducts
  - *Regulating services*: water quality, habitat, C sequestration, GHG reduction, flood control, etc. are part of the design
  - Economic models accounts for both
  - Conceptual model focuses beyond mitigating impacts, on "how to design"
  - Diversified business model distributes risk

HOW CAN WE LEVERAGE ECOSYSTEM SERVICES IN BIOENERGY?

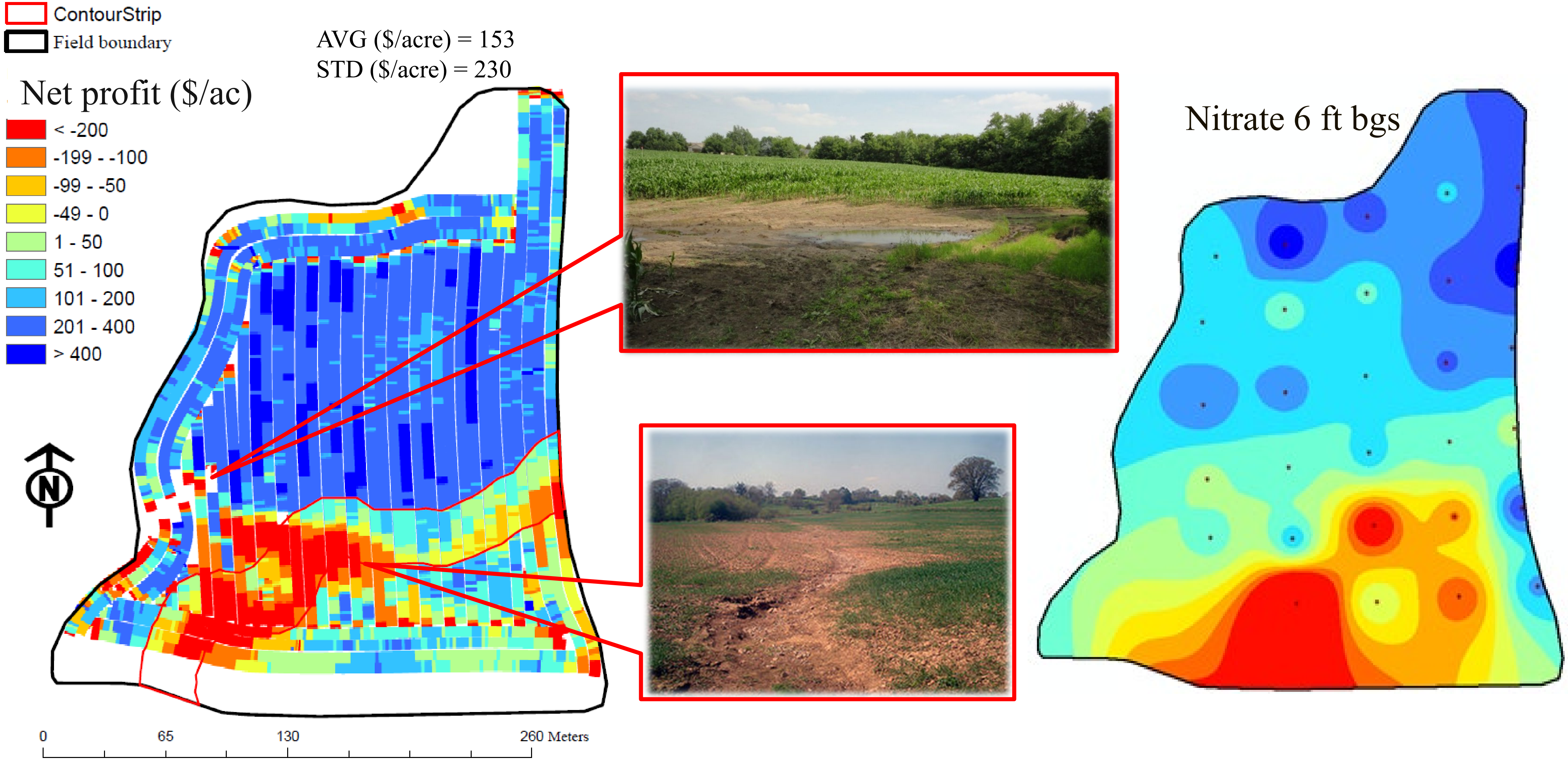
1. Design of production landscapes
    - Identification of Ecosystem Services goals
2. Quantification
3. Valuation
4. (policy, regulatory, or voluntary action)
5. Payment framework

Decision-making frameworks

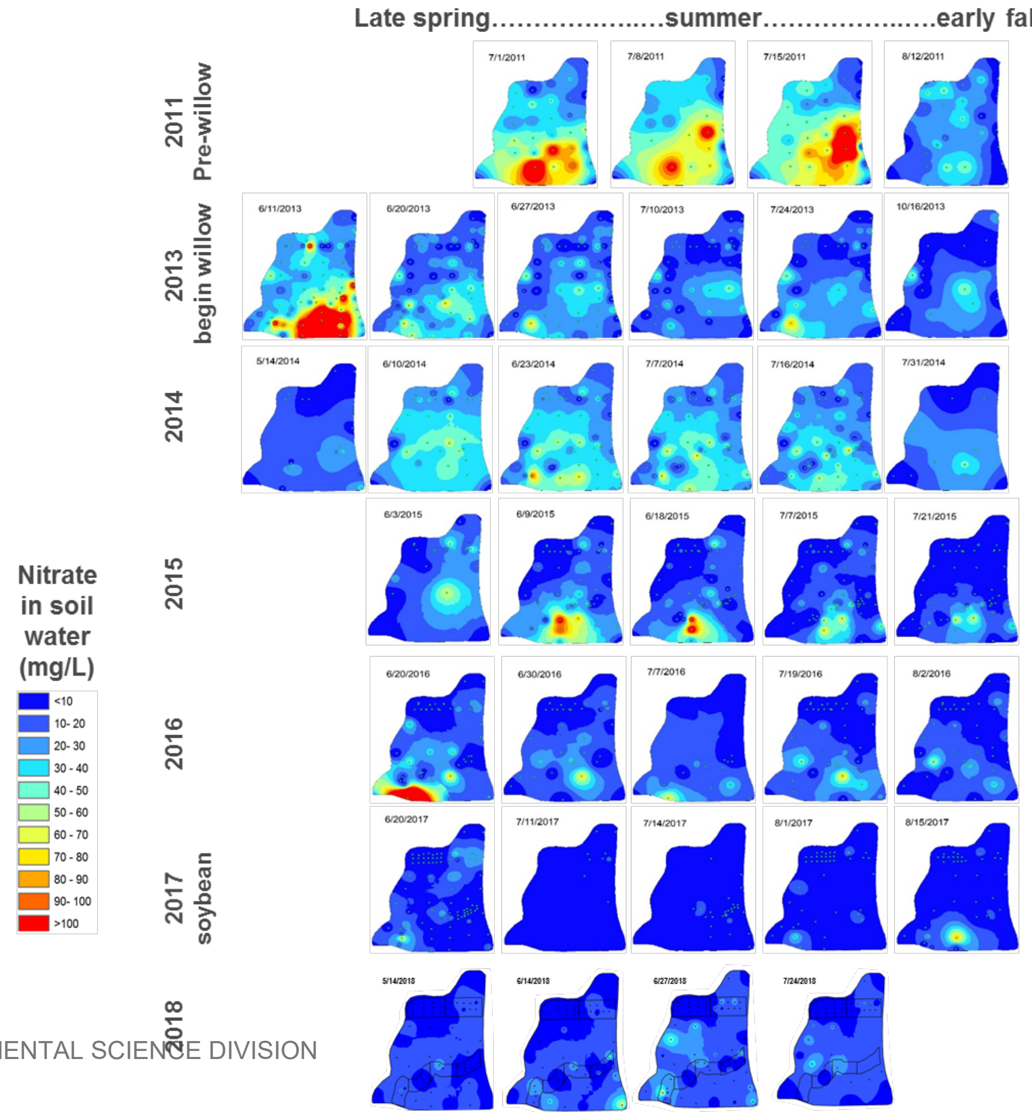
- Cost –benefit analysis
- Environmental impact assessment
- Programmatic environmental impact assessment
- Lifecycle analysis
- Risk assessment
- Techno-economic analysis
- Multi-criteria analysis

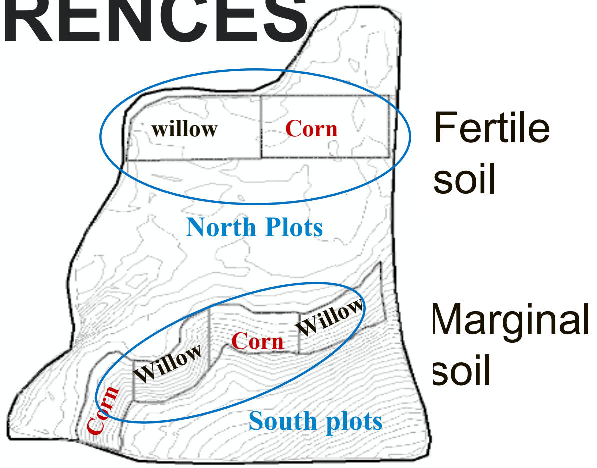
TOWARDS A TOTAL ECONOMIC VALUATION OF LANDSCAPE MANAGEMENT

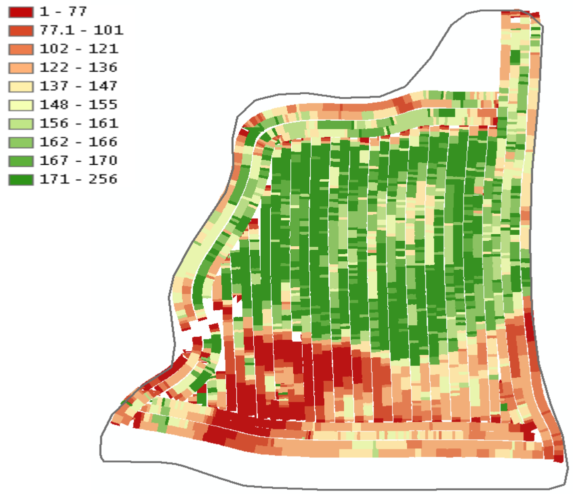
ECONOMIC LOSSES AND ENVIRONMENTAL CONCERNS OFTEN GO TOGETHER



SOIL WATER NITRATE CONCENTRATION (AT 5 FT BGS) HAS SEASONAL RECURRENCES

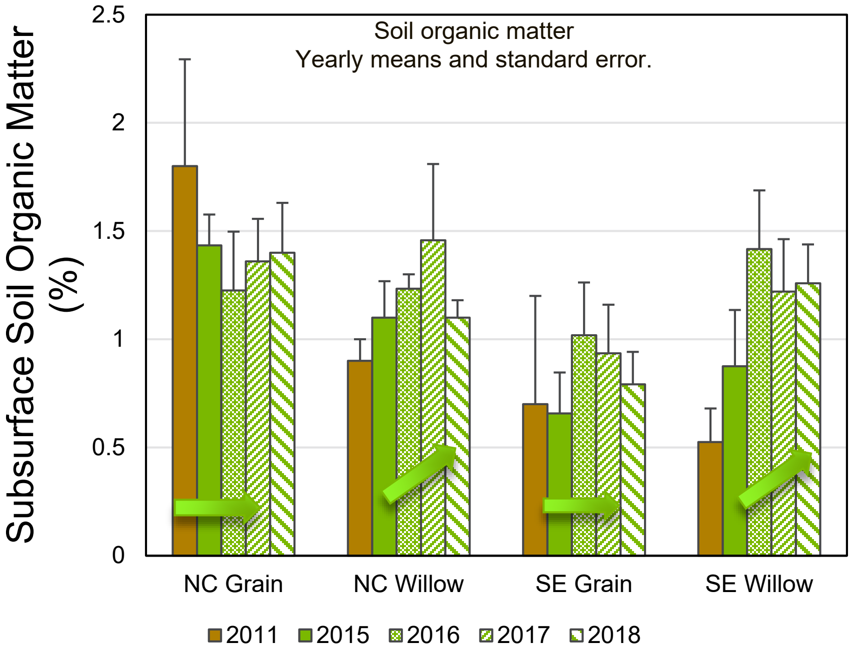




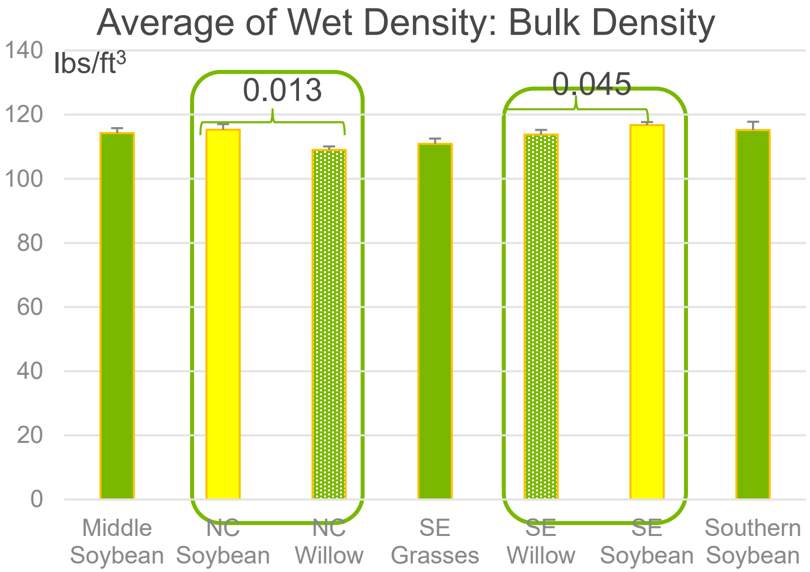


Yield map: areas of **low** (RED) and **high** (GREEN) yields (bu/ac). Low yield areas coincide with high nitrate losses.

SOIL QUALITY AND GHG EMISSIONS



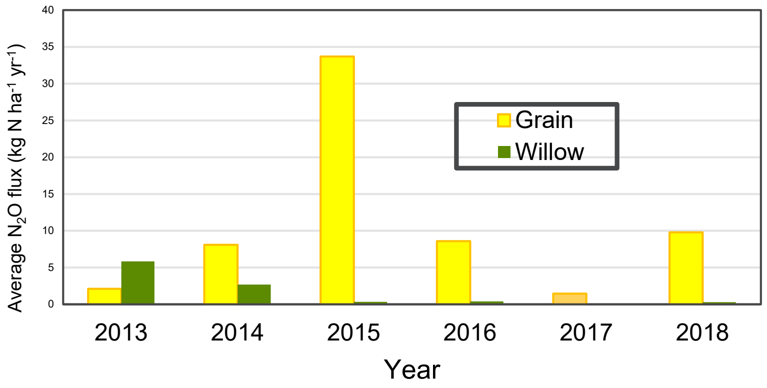
Subsoil samples collected from the bottom 6 inches of a 4-foot core. Zumpf et al. (2017)

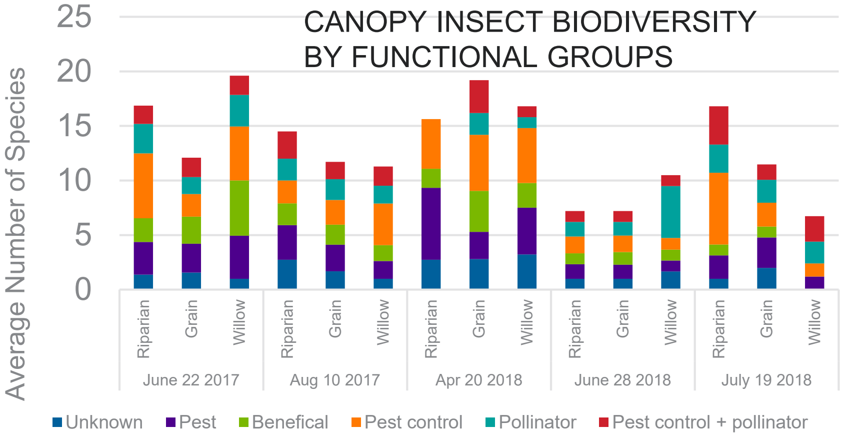


Troxler 3440 moisture-density gauge on June 14th and June 15th, 2017

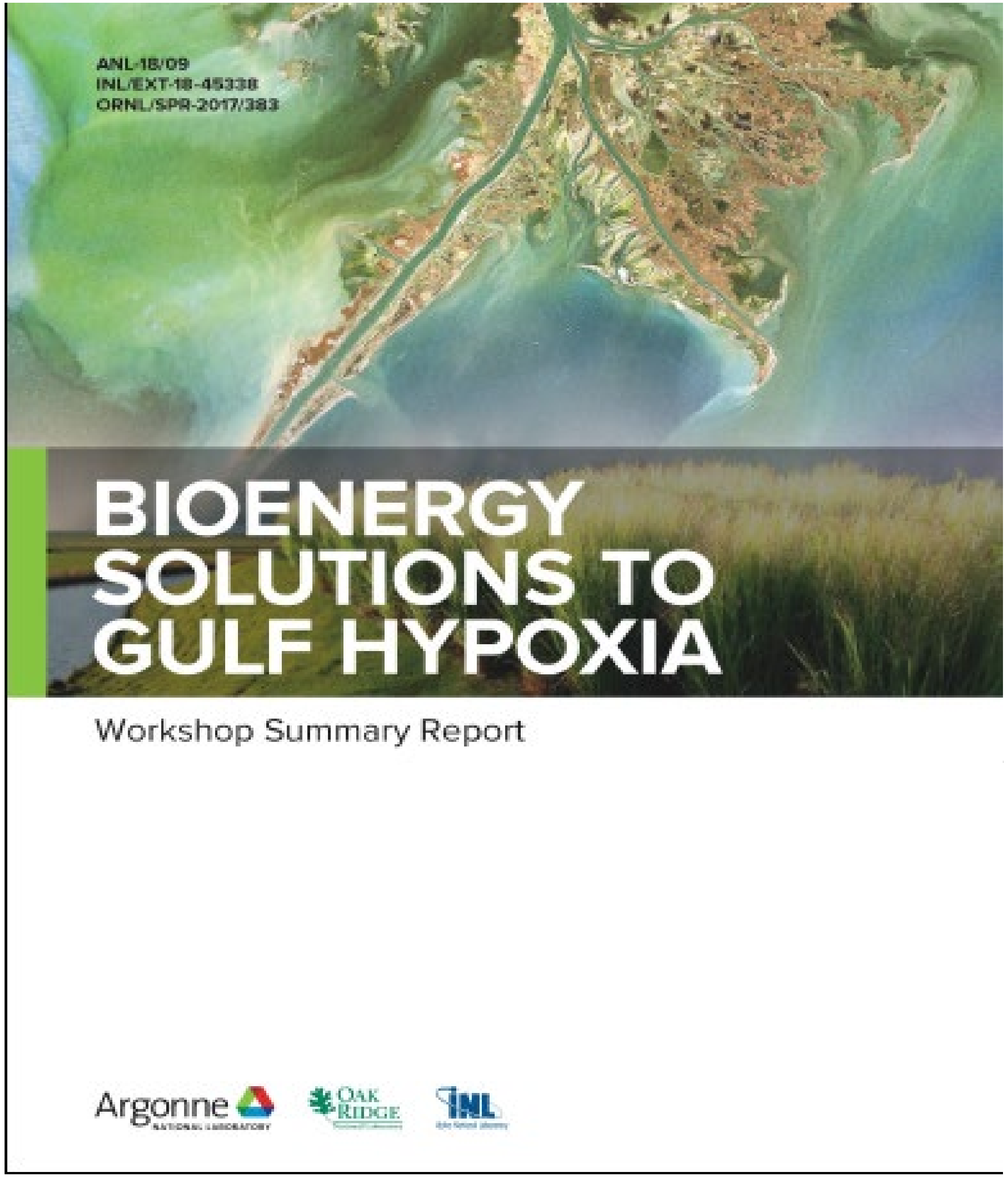
Significantly lower bulk density under willow than soybean

N_2O FLUXES

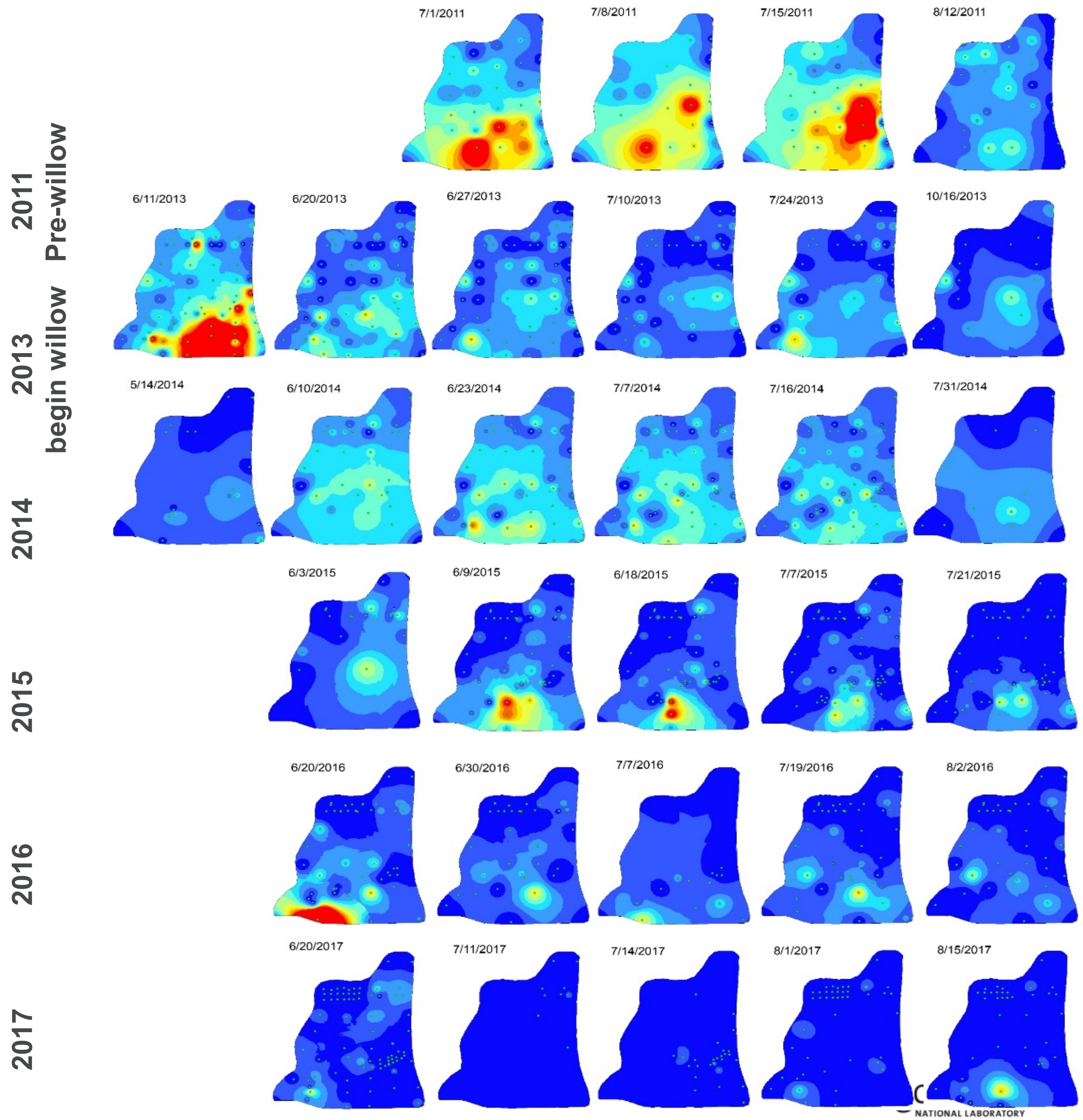




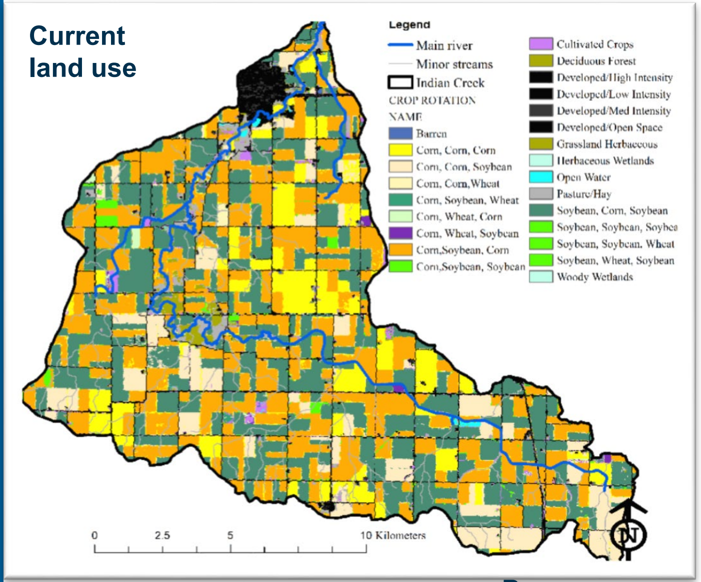
EXAMPLE: WATER QUALITY

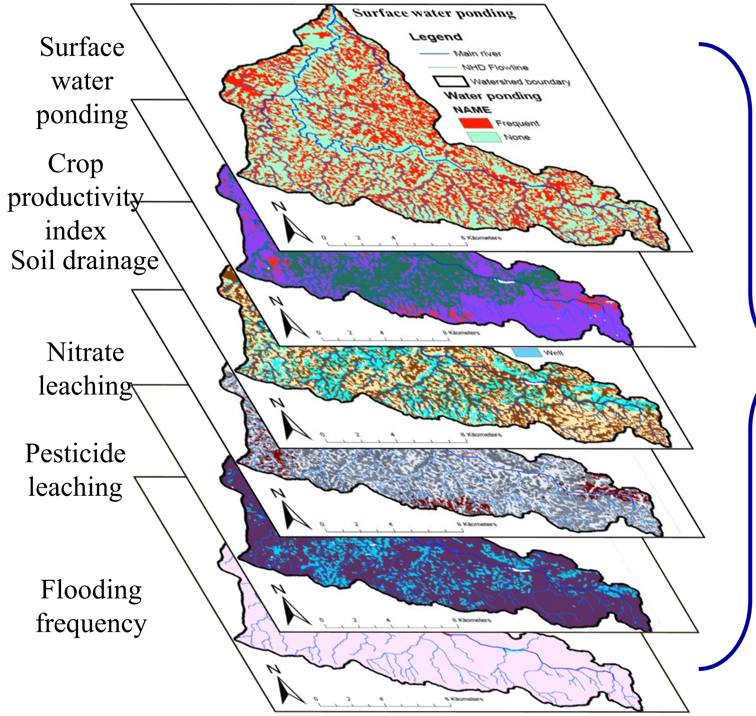


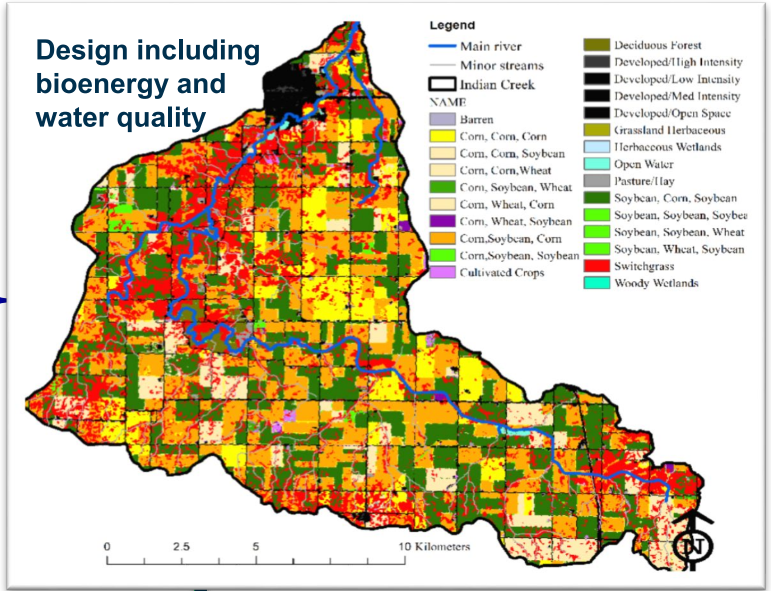
Late spring……………………..….summer……………..……….….early fall

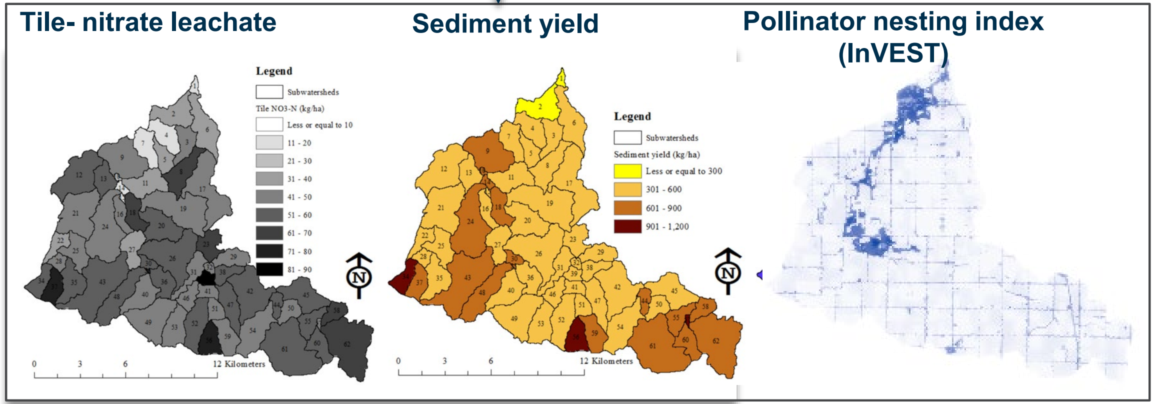


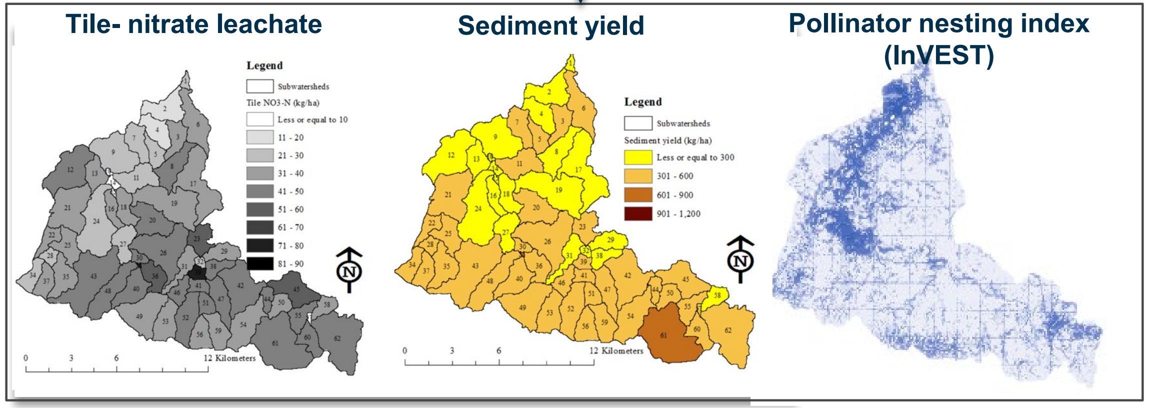
WATERSHED DESIGN INCREASES ES IN MARGINAL LAND











Ssegane et al., 2016

THERE ARE TRADEOFFS

Ecosystem Services framework implies system level thinking to maximize benefits.

Meehan et al., 2013

PLOS | ONE

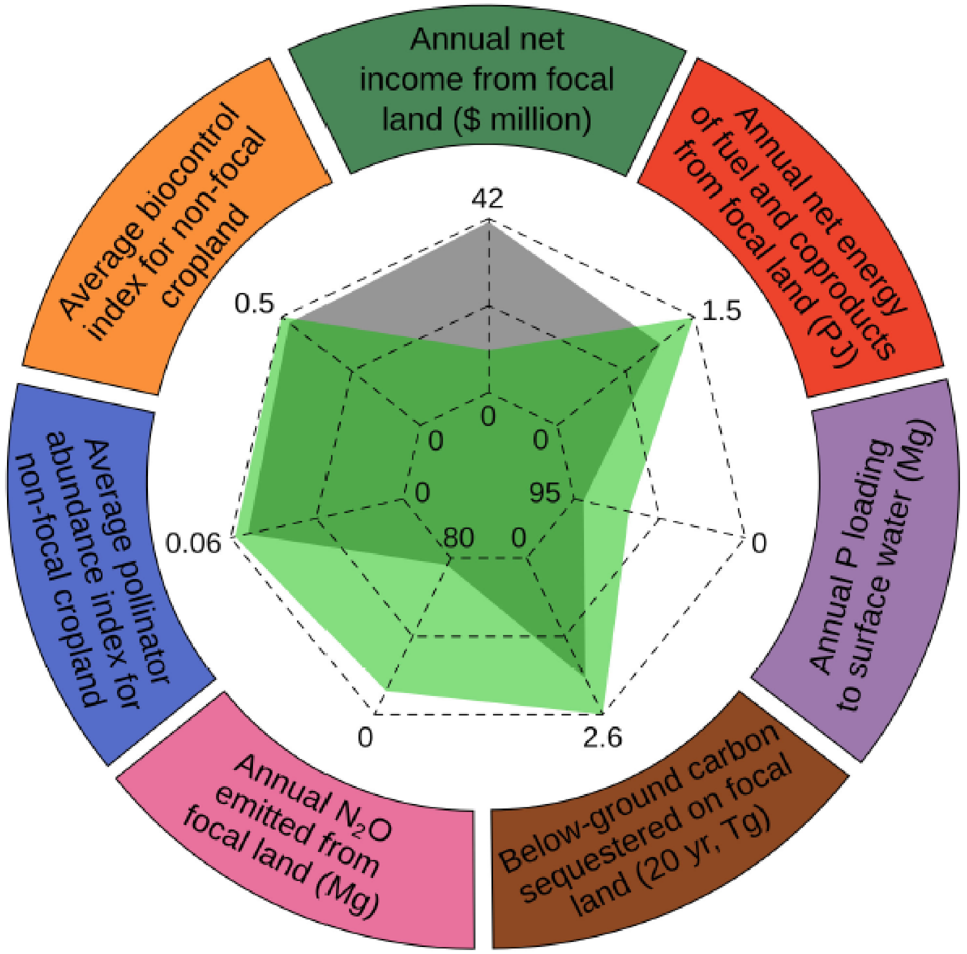
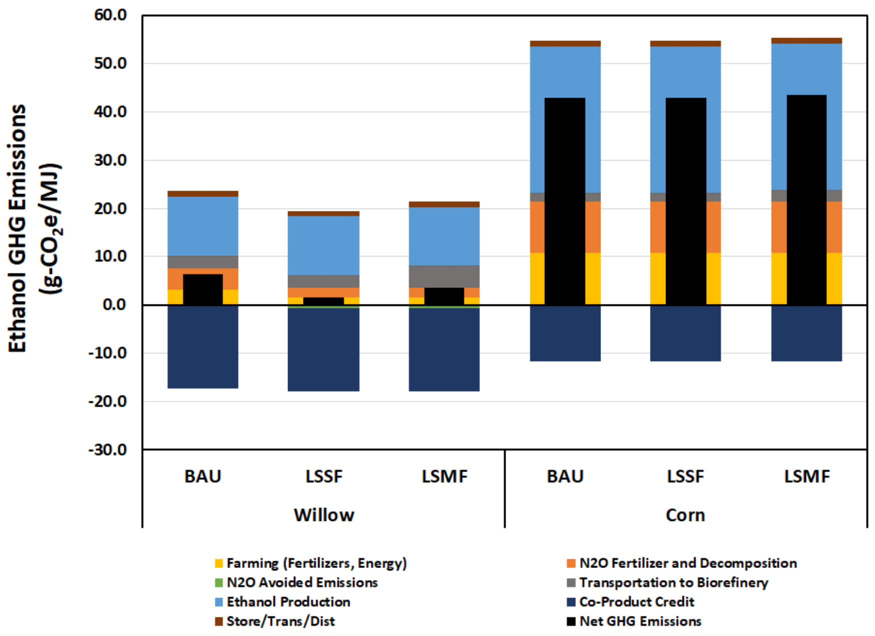


Figure 2. Ecosystem services from focal land. Seven ecosystem services derived from 16,727 hectares of focal land under continuous-corn (gray polygon at center) and perennial-grass (green polygon at center) bioenergy scenarios. Note that axes for phosphorus pollution and nitrous oxide emission are reversed so that the most positive environmental outcomes are consistently furthest from the origin.

doi: 10.1371/journal.pone.0080093.g002

COST OF N REMOVAL – COMPARING CONSERVATION PRACTICES

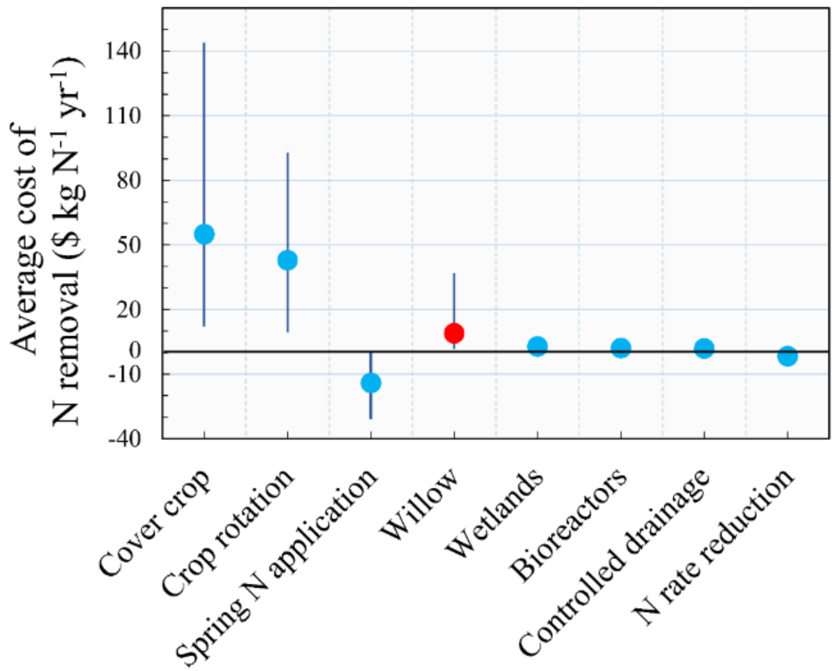
Bioenergy buffers - cost competitive as a conservation option and GHG-sparing



GHG emissions from producing willow on marginal land were less than half of those from producing corn on that land.

- Most benefit is due to less fertilizer, energy, agrichemicals in willow plots
- Sensitivity analysis: results most sensitive to willow yield

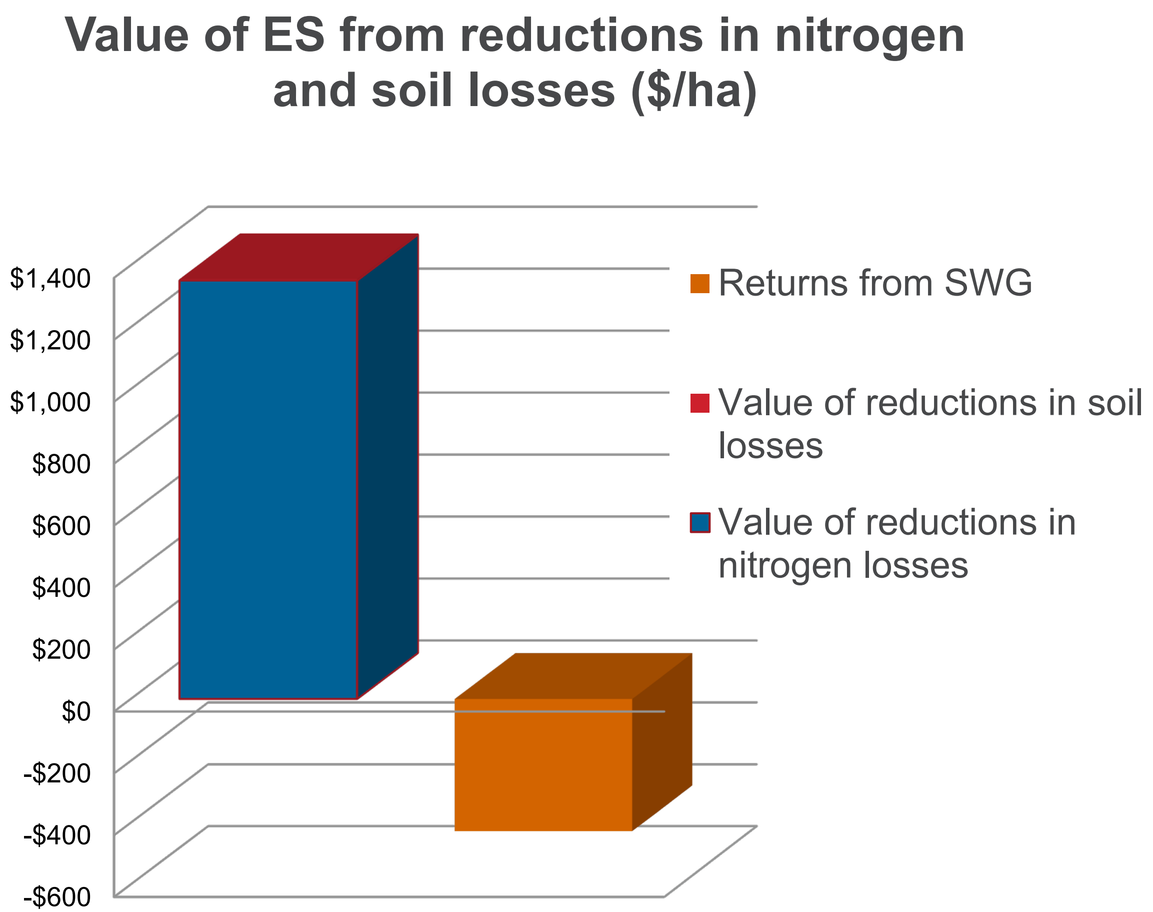
Adapted from Christianson L, Tyndall J, Helmers M. (2013)



H. Ssegane, C. Zumpf, M. C. Negri, P. Campbell, J. Heavey, and T.A. Volk (2016) -**The Economics of Growing Shrub Willow as a Bioenergy Buffer on Agricultural Fields. A case study in the Midwest Corn Belt**. Biofuels, Bioproducts and Biorefining. DOI: 10:1002/bbb.1679.

TOTAL ECONOMIC VALUE AND ECOSYSTEM VALUATION

1. **Market price method** – can be applied to commodities traded on the market, e.g. oil, corn etc.
2. **Productivity method** – can be used for ecosystem services that contribute to the production of commodities, e.g. fresh water in an aquaculture pond.
3. **Hedonic price method** – can be used for ecosystem services that affect the economic value of other commodities, e.g. a forest which increases the value of properties around it.
4. **Travel cost method** – can measure the value of recreational areas by calculating how much people will pay to travel to and visit those sites.
5. **Damage cost avoided, replacement cost and substitute cost methods** – can measure the cost of avoided damage to ecosystem services, of replacing or providing substitutes for those services, e.g. the cost of artificial crop pollination in the absence of bees and other pollinating insects.
6. **Contingent valuation method** – can be used to elicit the value of any ecosystem service based on asking people to choose between ecosystem services.
7. **Benefit transfer method** – estimates the value of ecosystem services based on an already completed valuation in another place.



In collaboration with S. Secchi and J. Kozak, SIU

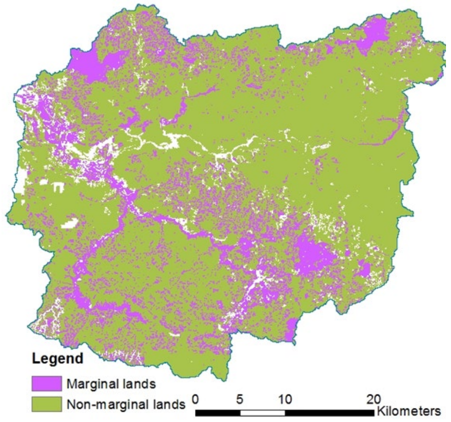
http://www.ceeweb.org/work-areas/priority-areas/ecosystem-services/how-to-value-ecosystem-services/

PROVISIONING REVENUE UNDER BAU AND ABL LANDSCAPE SCENARIOS - VERMILION WATERSHED

Crops	Yield (kg/ha)	Production (Mg)	Value (2016 $ million)		
Business as usual (BAU) scenario					
Corn	8,428	5,695,861	769.11		
Soybeans	3,504	1,561,799	565.20		
Switchgrass	0	0	0.00		
Total			1,334.31		

Crops	Yield (kg/ha)	Production (Mg)	Value (2016 $ million) at switchgrass price		
			$20/Mg	$50/Mg	$80/Mg
Alternative bioenergy landscape (ABL) scenario					
Corn	8,513	5,626,550	759.75	759.75	759.75
Soybeans	3,505	1,527,733	552.87	552.87	552.87
Switchgrass	7,604	223,432	4.47	11.17	17.87
Total			1,317.09	1,323.80	1,330.50

Marginal land identified in Upper Vermilion: 29,300 ha

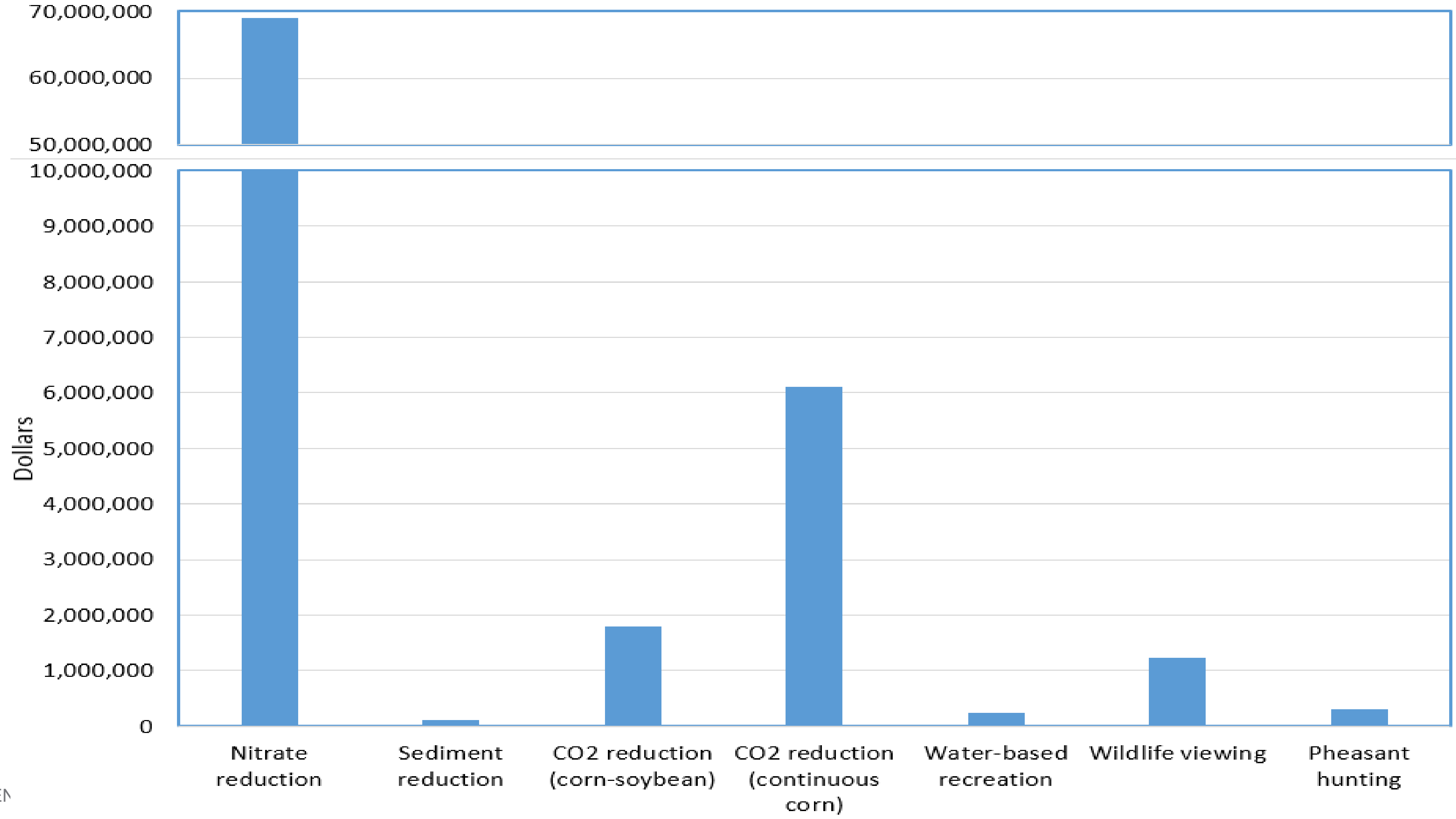


THE VALUE OF ECOSYSTEM SERVICES USED FOR BENEFIT TRANSFER

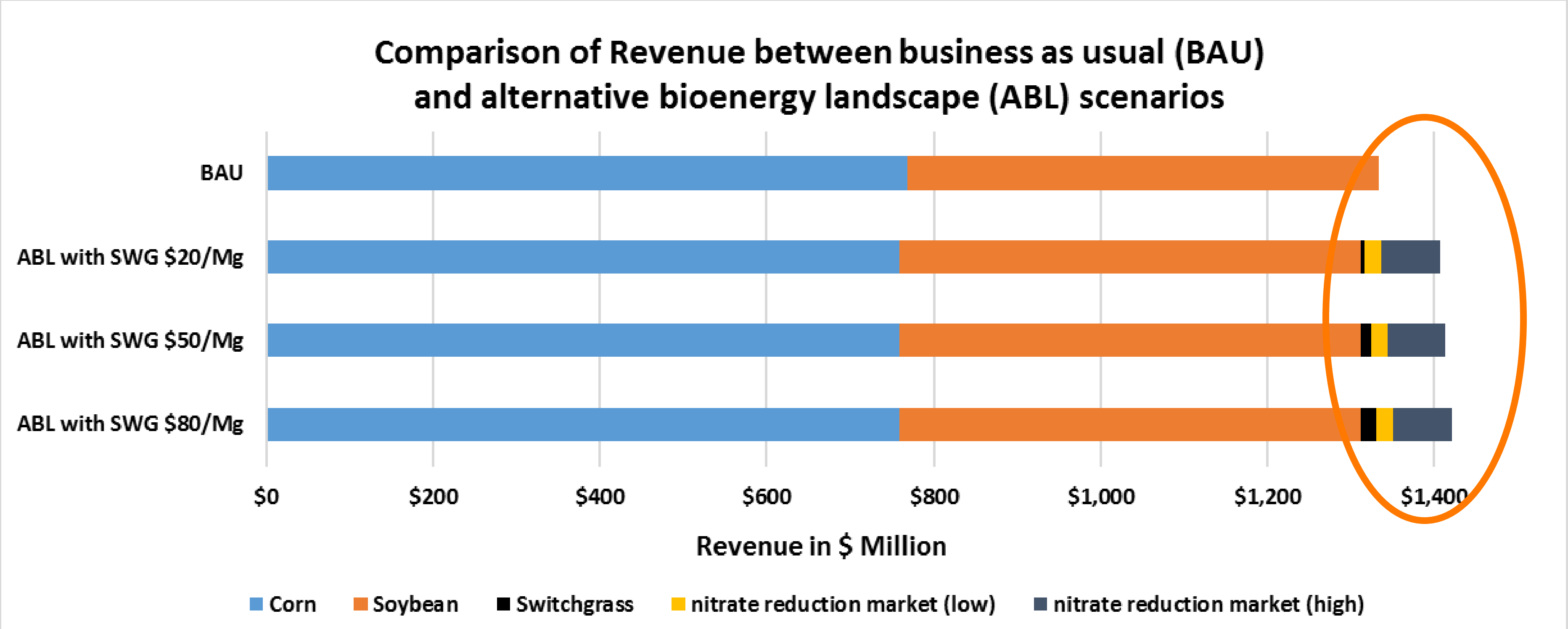
Ecosystem Service	Source	2016 Dollars
Nitrate reduction	Ribaudo et al. (2005)	$38.37 per kg nitrogen
Sediment reduction	Hansen and Ribaudo (2008)	$4.35 per Mg
Carbon sequestration	Interagency Working group (2016); Bhattarai et al. (2017)	$209.10 and $61.07 per ha per year*
Water-based recreation	Baylis et al. (2002)	$3.45 to $8.21 per ha
Wildlife viewing	Feather et al. (1999)	$42.36 per ha
Pheasant hunting	Feather et al. (1999)	$9.97 per ha

*Based on Price of $33.19 per Mg CO2eq (Interagency Working group 2016), and Quantity of 6.3 Mg CO_2eq per ha per year for continuous corn to switchgrass, and 1.84 Mg CO_2eq per ha per year corn-soy rotation to switchgrass (Bhattarai et al. 2017)

VERMILION WIDE BIOENERGY DESIGN ECOSYSTEM SERVICES VALUE



RESULTS FOR UPPER VERMILION WATERSHED



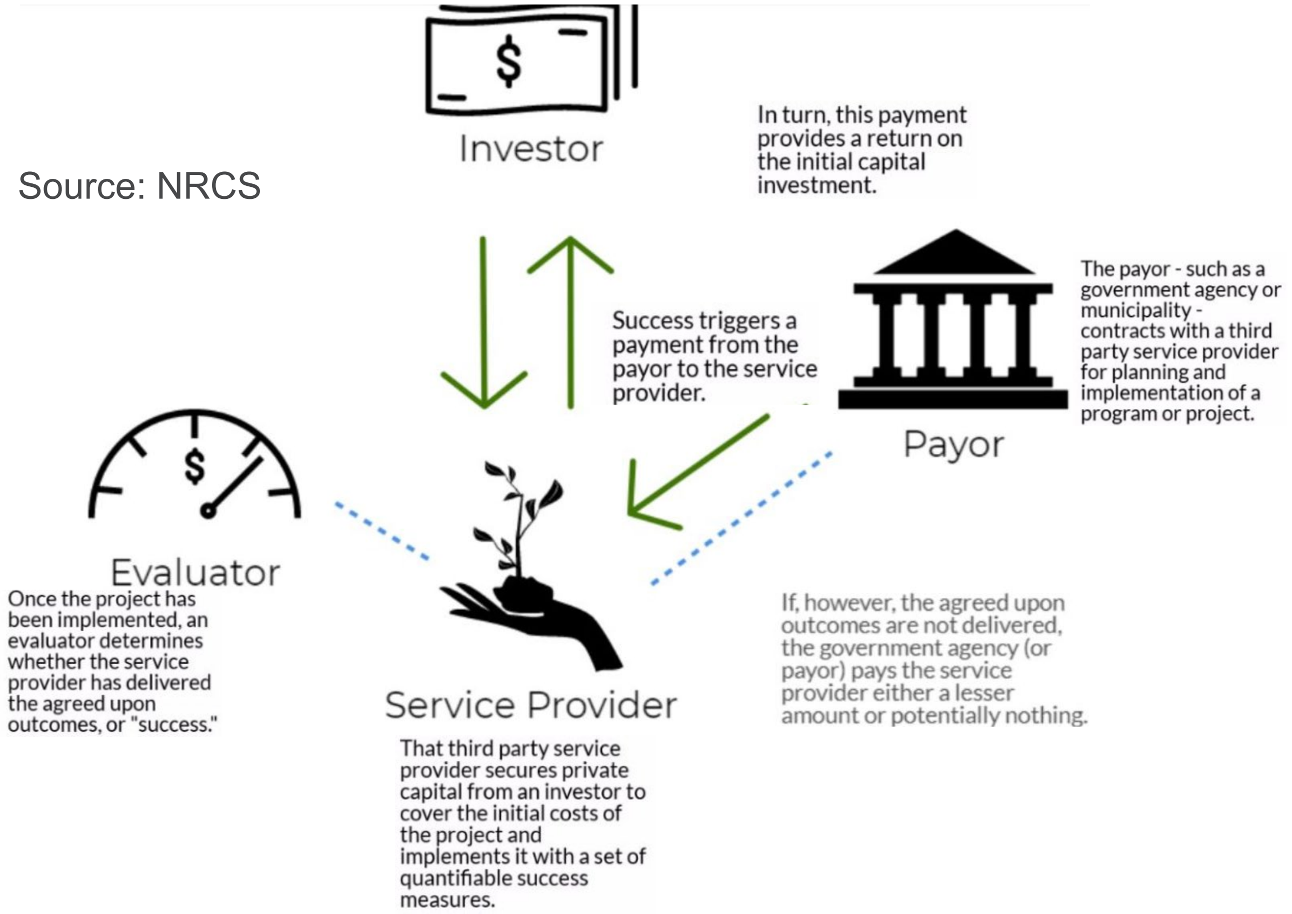
- Replacement of commodity crops in marginal land by switchgrass results in slightly decreased overall value for the commodity crops
- However, inclusion of ES valuation could change situation to a positive
- Value of reduced nitrate *alone* would create a net gain of $20 to $90 million, depending on market for nitrate reduction. (others examined: nitrate loss reduction, erosion/sedimentation, GHG, water-based recreation, wildlife viewing, hunting, and pollinator services)

Mishra et al., (2019) https://onlinelibrary.wiley.com/doi/abs/10.1111/gcbb.12602

ANY CHANCES IT COULD HAPPEN?

PRIVATE- PUBLIC MECHANISMS FOR ECOSYSTEM SERVICES PAYMENT

Source: NRCS



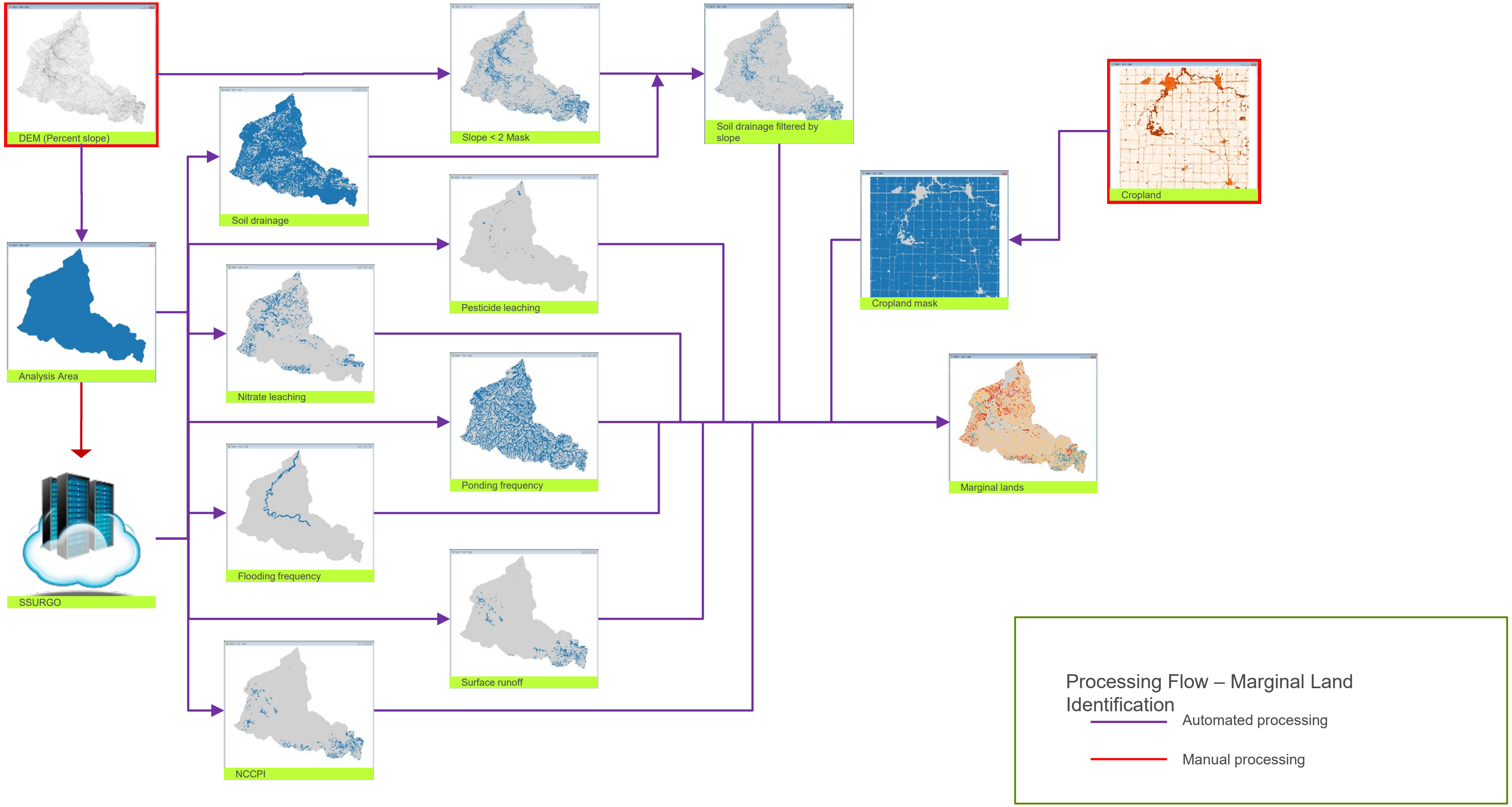
- i2 Capital's project, with The Nature Conservancy, Quantified Ventures, and other partners in the Brandywine-Christina watershed (Delaware, Maryland, and Pennsylvania).
- American Rivers - in partnership with Environmental Defense Fund and other non-profits, agencies, and utilities - created the Central Valley Habitat Exchange.
- Ohio River Basin Interstate Water Quality Trading Project (funded by EPRI)
- Fox River Valley Phosphorus Trading Program Fox-Wolf Watershed Alliance, Brown County, Outagamie County Land Conservation Department, the Wisconsin Department of Natural Resources, Great Lakes Commission, and the USDA NRCS.

Source: http://nrcs.maps.arcgis.com/apps/Cascade/index.html?appid=769a0ef44b1b4d7b85d6e02c0ba7630d

THE PATH FORWARD

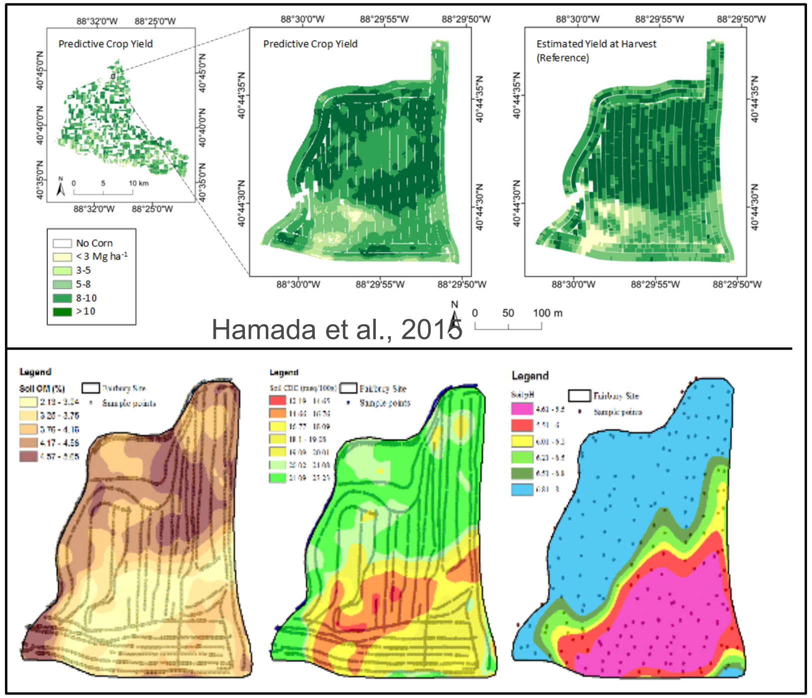
- Learning from examples, the good AND the bad
- Research needs to address many unknowns:
  - Understanding lag times and permanence of ES
  - Cumulative effects and buffering
  - Scales of resolution – are current methods scalable and appropriate for the precision required?
  - Working on trust, understanding and reducing uncertainties
- *An opportunity: the ES of resilience to extreme events, tipping points and climate change*
- Social science needs to drive the change!

PATH FORWARD 1: MAKING SCALING UP FASTER AND EASIER



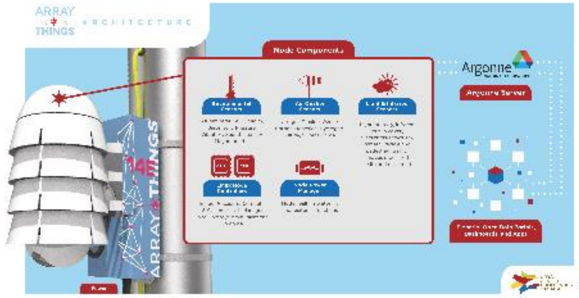
PATH FORWARD 2: SENSORS AND DATA
THE CONCEPT OF OBSERVATORY FOR SYNERGISTIC RESEARCH

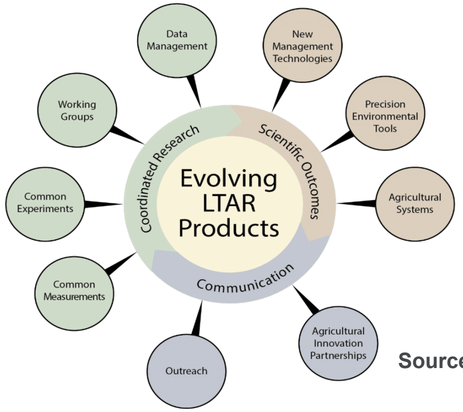
- Strength is in the numbers: data, data and more data
- Remote sensing, proximal sensing, distributed sensing, and edge computing
- Observatory concept allows for more leveraging of research investments, larger opportunities for meta-studies – learning from existing examples to bring bioenergy field trials together.



Hamada et al., 2015

Source: Argonne National Laboratory





Source: USDA LTAR

THANK YOU ! QUESTIONS?

Acknowledgements

- Herbert Ssegane, Jules Cacho, Patty Campbell, Colleen Zumpf, John Quinn, Nora Grasse, Argonne National Laboratory
- The many students who help us every summer in the field
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- Kristen Johnson and Alicia Lindauer, DOE-BETO
- Paul Kilgus and Ray Popejoy, Fairbury IL
- The Livingston County IL SWCD and NRCS

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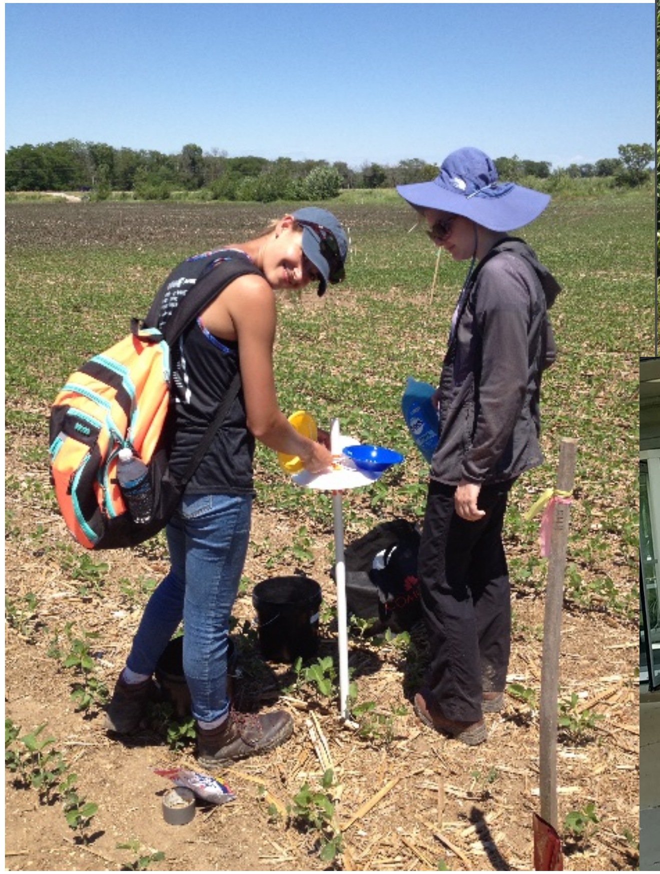

Our most recent summer interns