Aviation, Agriculture, and Water Quality: A Triple Win for Sustainability?

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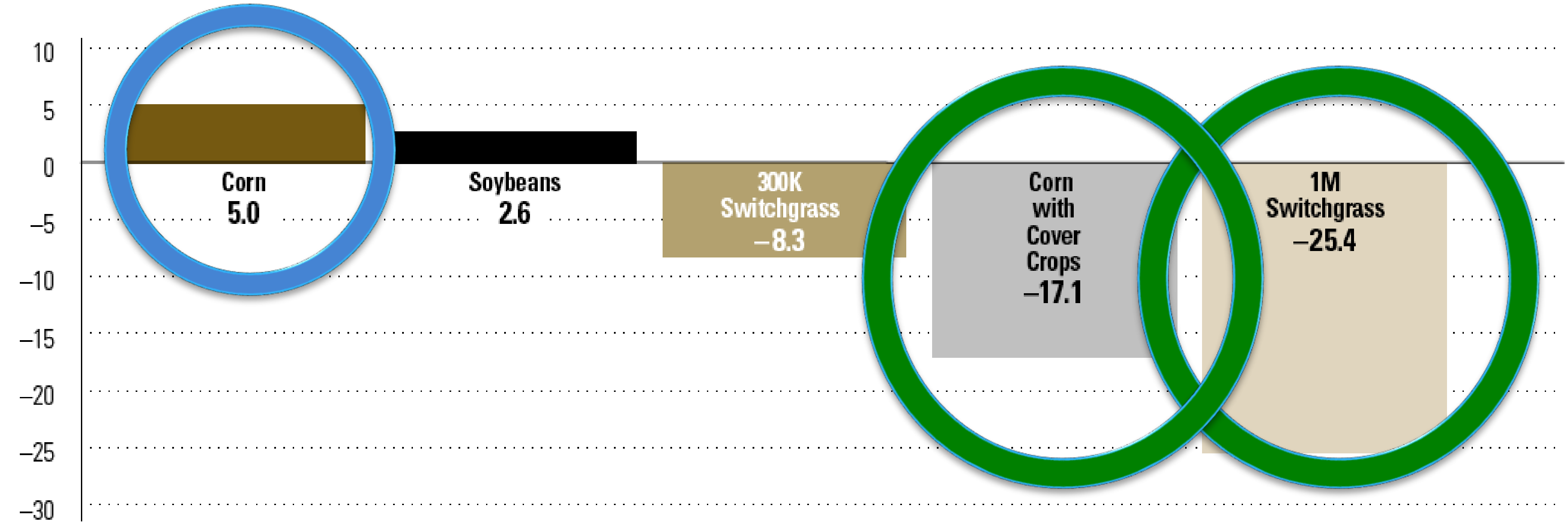
Biofuels and the Bay – From 2008 to Today

Maximum Nitrogen Load Changes for Biofuels

Millions of pounds per year of nitrogen delivered from the Chesapeake Bay watershed to the Bay under five modeling scenarios.



Assumptions for Alternative Scenarios:

- **Corn:** 300,000 additional acres of corn with typical levels of management practices
- **Soybeans:** 300,000 additional acres of soybeans with typical levels of management practices
- **300K Switchgrass:** 300,000 acres of switchgrass, converted primarily from hay and pastureland, with no fertilization
- **Corn with Cover Crops:** Cover crops on all existing and new (additional 300,000) corn acres and one quarter of all other row crops, watershed-wide.
- **1M Switchgrass:** 1 million acres of switchgrass, converted primarily from hay and pastureland, with no fertilization

SOURCE: U.S. EPA CHESAPEAKE BAY PROGRAM OFFICE

Opportunities for a Regional Bioeconomy

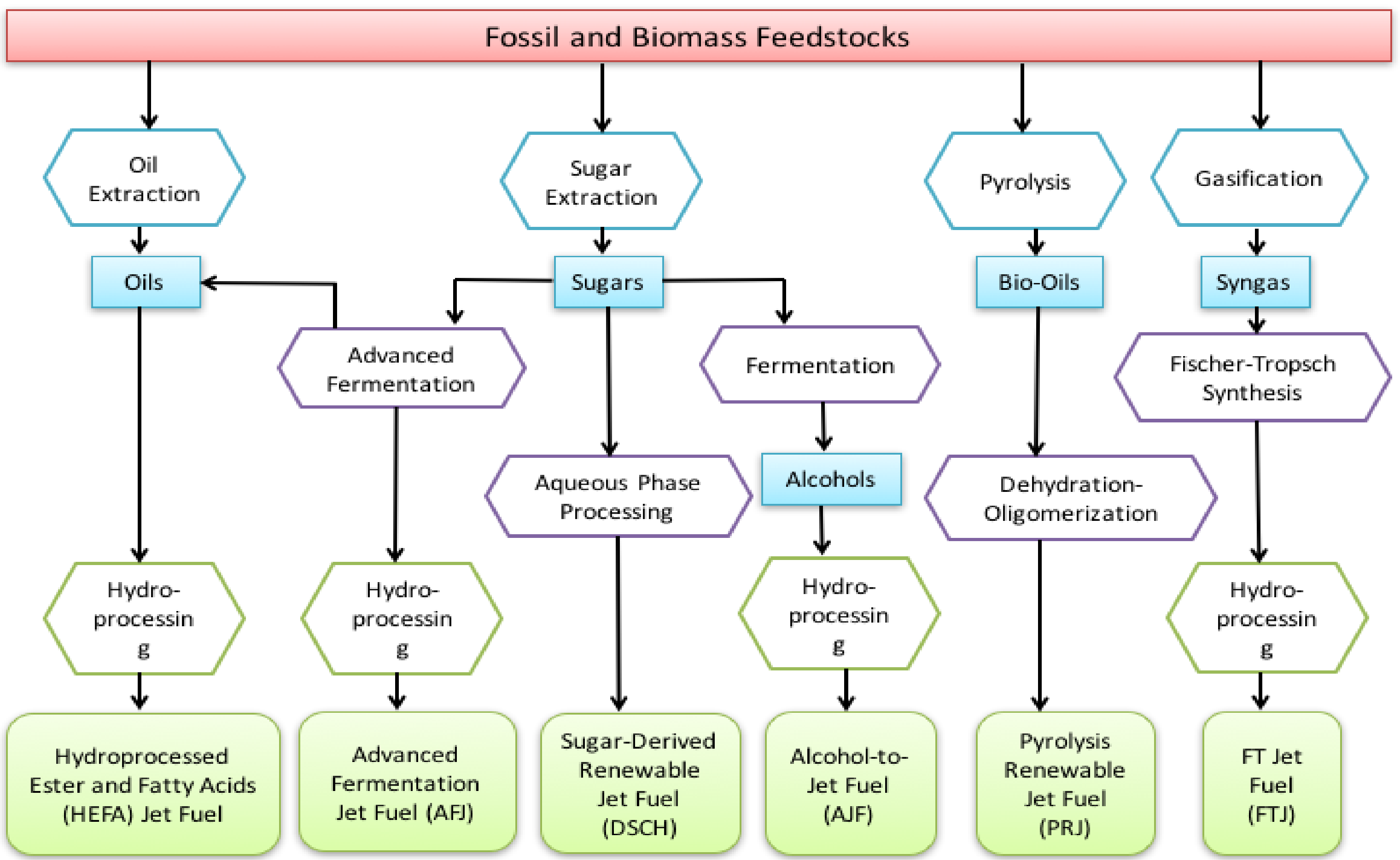
Aviation and Military Biofuels:

* Renmatix, global headquarters in King of Prussia, PA, partnering with Amyris Biotechnologies and Total to make jet fuel from cellulosic biomass.
* Delta, operating a former Conoco-Phillips refinery in Trainer, PA. Capacity: 3 billion gallons/year
* The Navy's Great Green Fleet
* Naval Station Norfolk
* BWI, Dulles, Philadelphia Airports

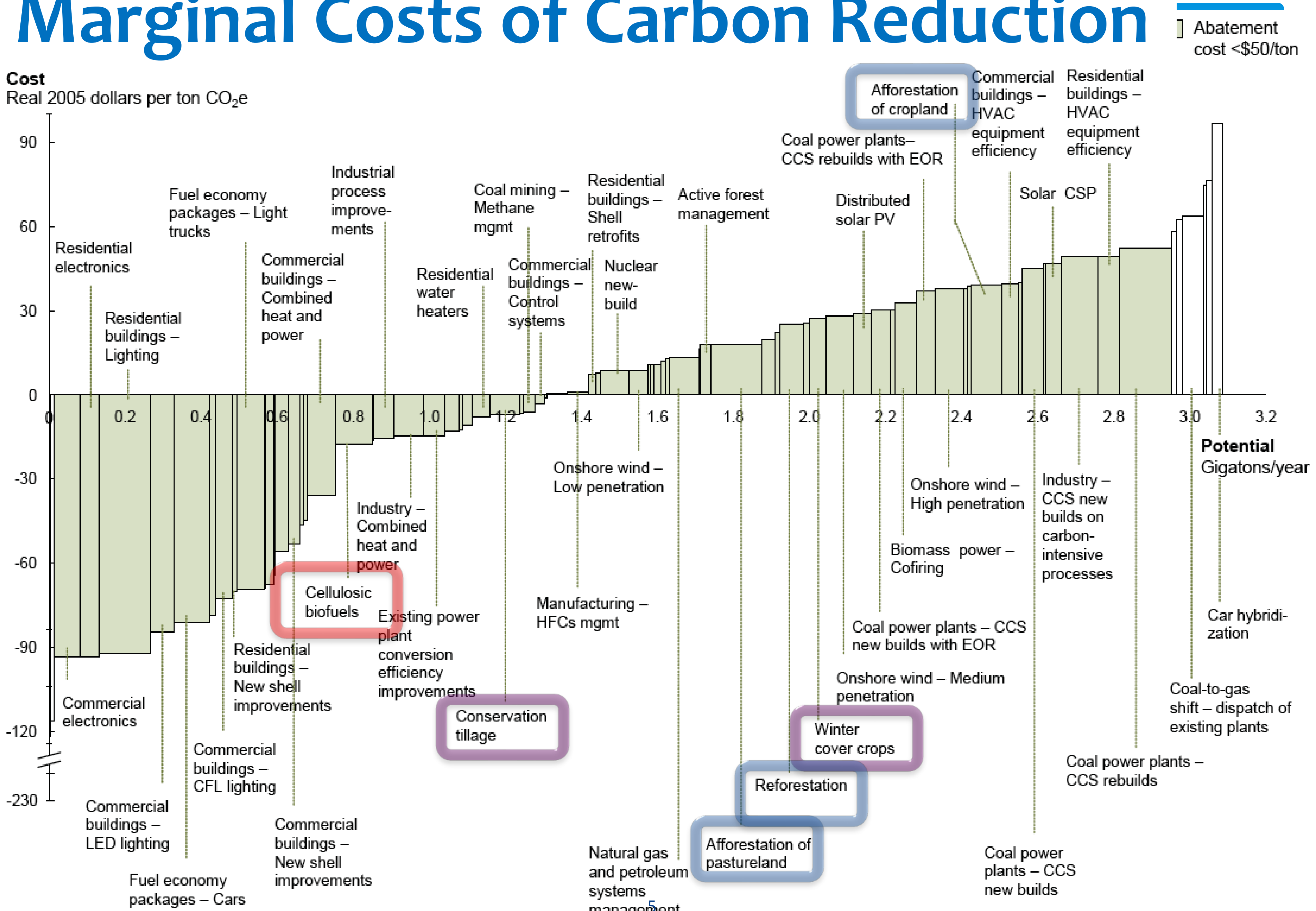
Other:

* Applied Biorefinery Sciences, CoolPlanet, Enchi, AgriTech
* Tranlin, building a $2 billion pulp mill in Chesterfield, VA

Many Paths to Aviation Biofuels



Marginal Costs of Carbon Reduction



US EPA/McKinsey; Enkvist et al. 2007

Conservation Feedstock: Shrub Willow

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Conservation Feedstock: Perennial Grasses

~~Perennial~~ Annual Biomass Crops

Winter Rye

* High uptake of N
* Highly digestable
* No conflict with food production

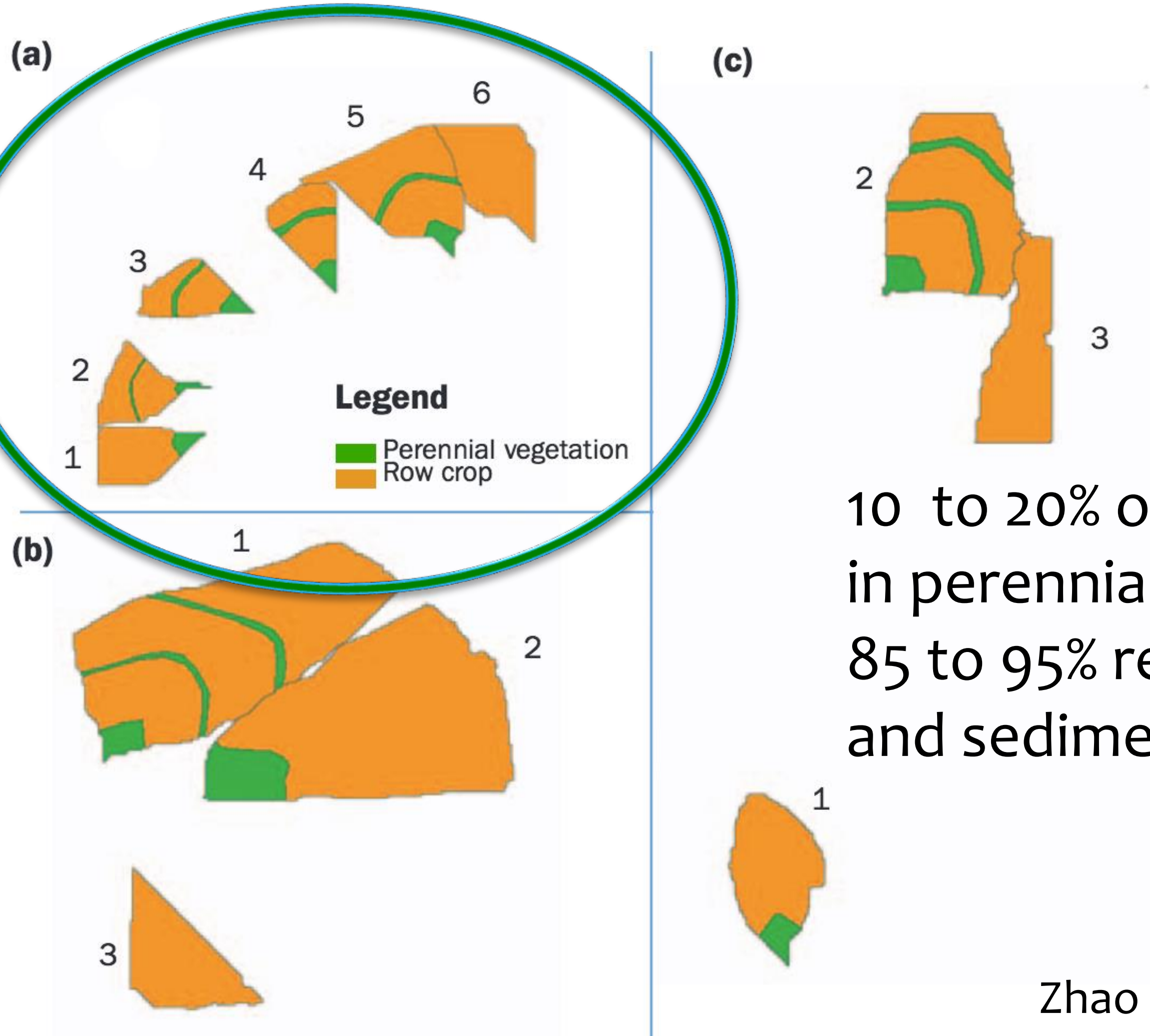
Biomass Sorghum

* High uptake of P
* Rotate with other summer annuals
* Use as bedding before producing energy

* Both also with multiple bioenergy/biofuel/biomaterial projects!

Landscape Design for Sustainability

Placement of prairie filter strips at (a) Basswood, (b) Interim, and (c) Orbweaver.



10 to 20% of the landscape in perennials results in 85 to 95% reductions in N, P and sediment!

Zhao et al. 2014

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Prairie Strips in Action – "Before"

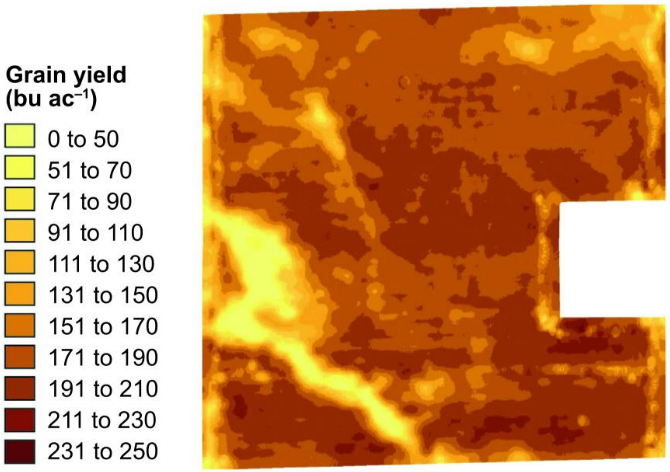
Prairie Strips in Action (early spring)

Working Buffers – by the numbers

* The Chesapeake Bay Watershed has 181,4400 miles of streams and rivers.
* WIPs require vegetative buffers for 70% of streambanks and shorelines. Currently at 58%. The difference represents 22,000 miles of new buffers.
* At 900 miles per year, this will take decades
* Each mile of two-sided 100 foot buffer = 24 acres.
* This represents 22,000 acres/year removed from production, and over 500,000 acres eventually – at $500/acre the lost revenue totals $250 million/year.
* Instead of an economic loss, these acres could produce 250 million gallons of biofuel, with revenue of >$1 billion/year for rural communities.

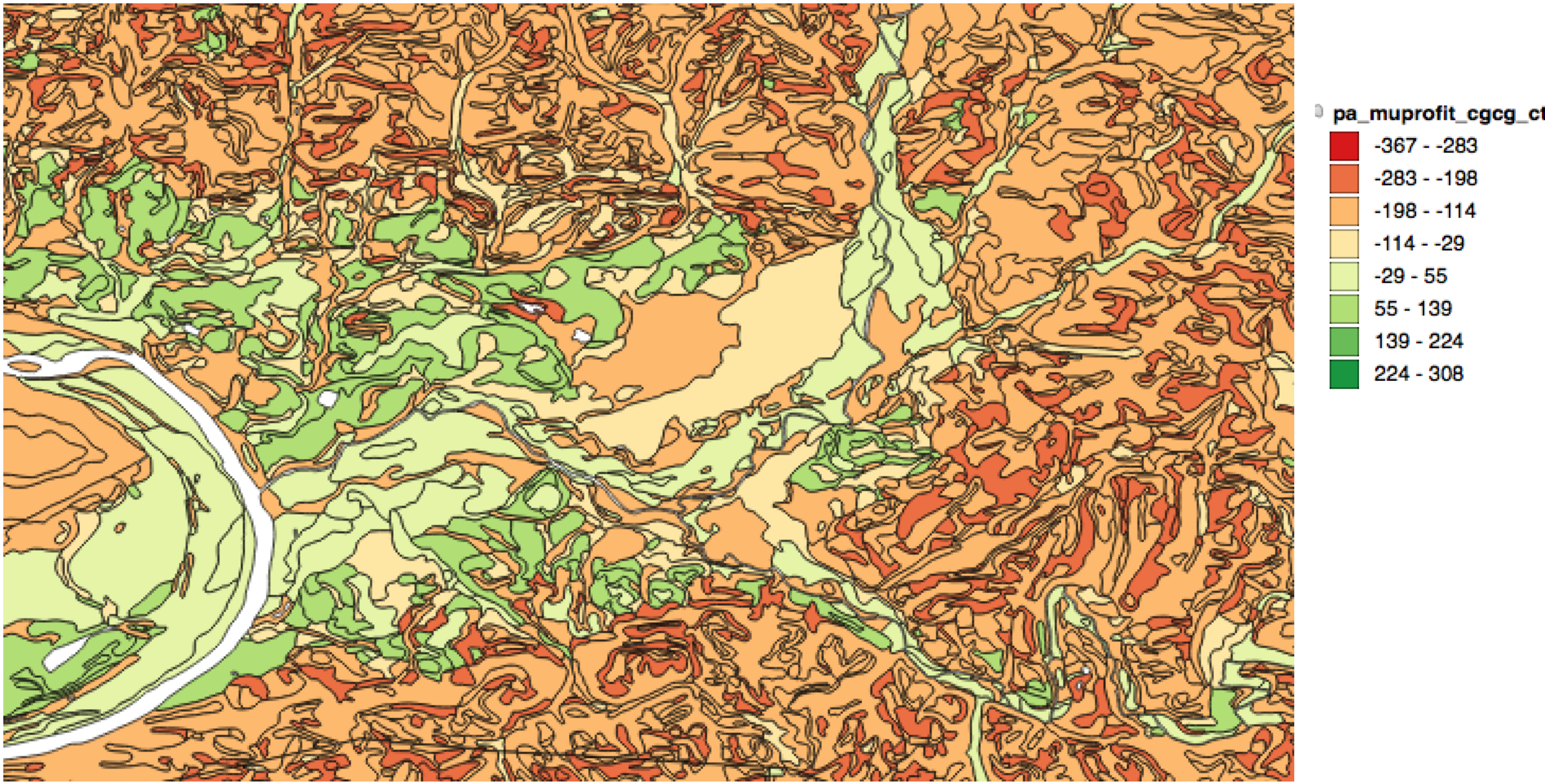
Yeoman Farmer meets The Internet of Things: Sub field economic analysis

- Since the dawn of agriculture, farmers have managed the landscape as fields. These fields were once small, but now are large. And they are far from uniform.
- Farmers have traditionally assessed profitability on the basis of a whole field. Precision agricultural tools allow much higher resolution. That knowledge now allows sub-field profit management.

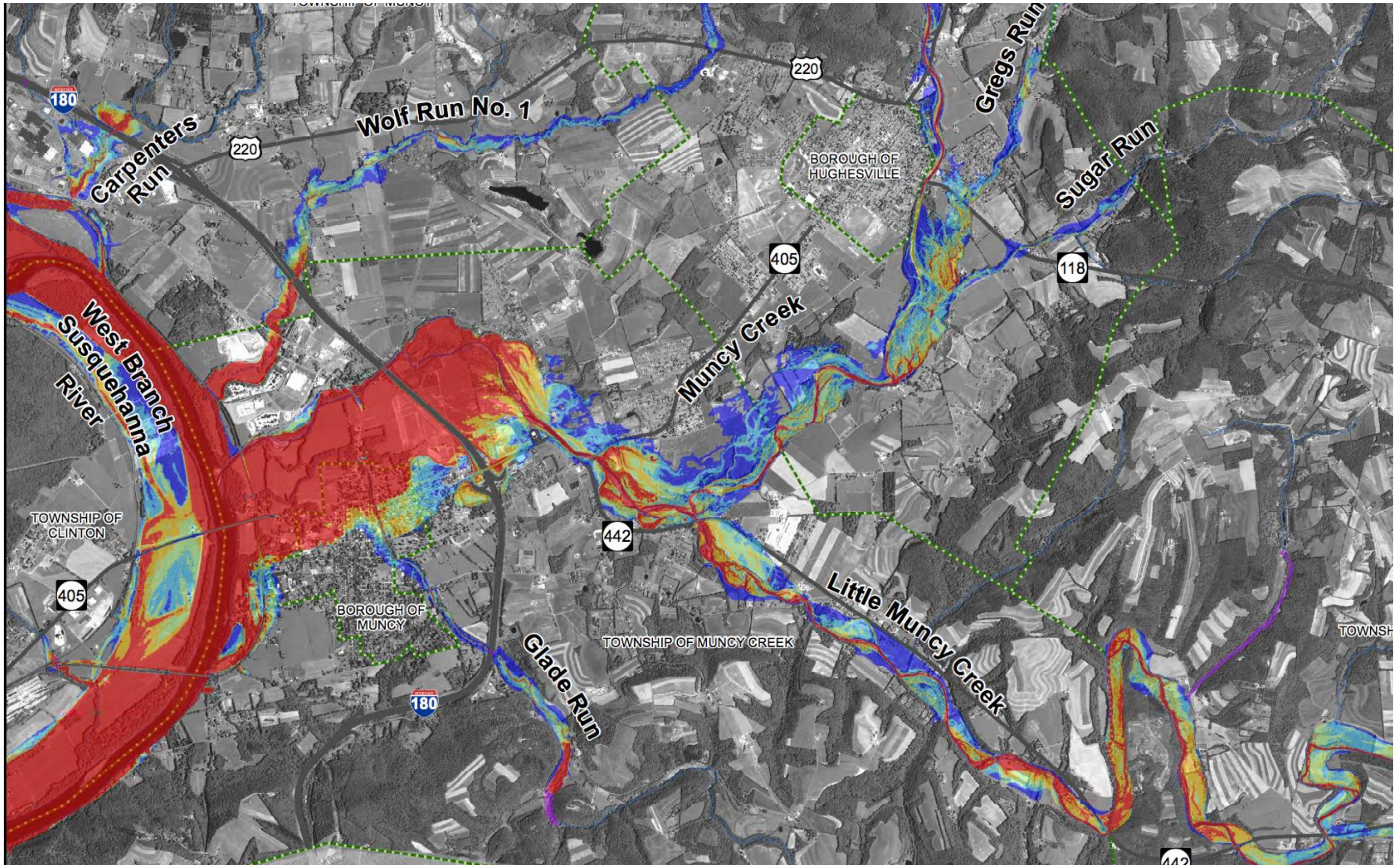


- Key question: To what extent do economically marginal regions of fields overlap with environmentally sensitive parts of the landscape?

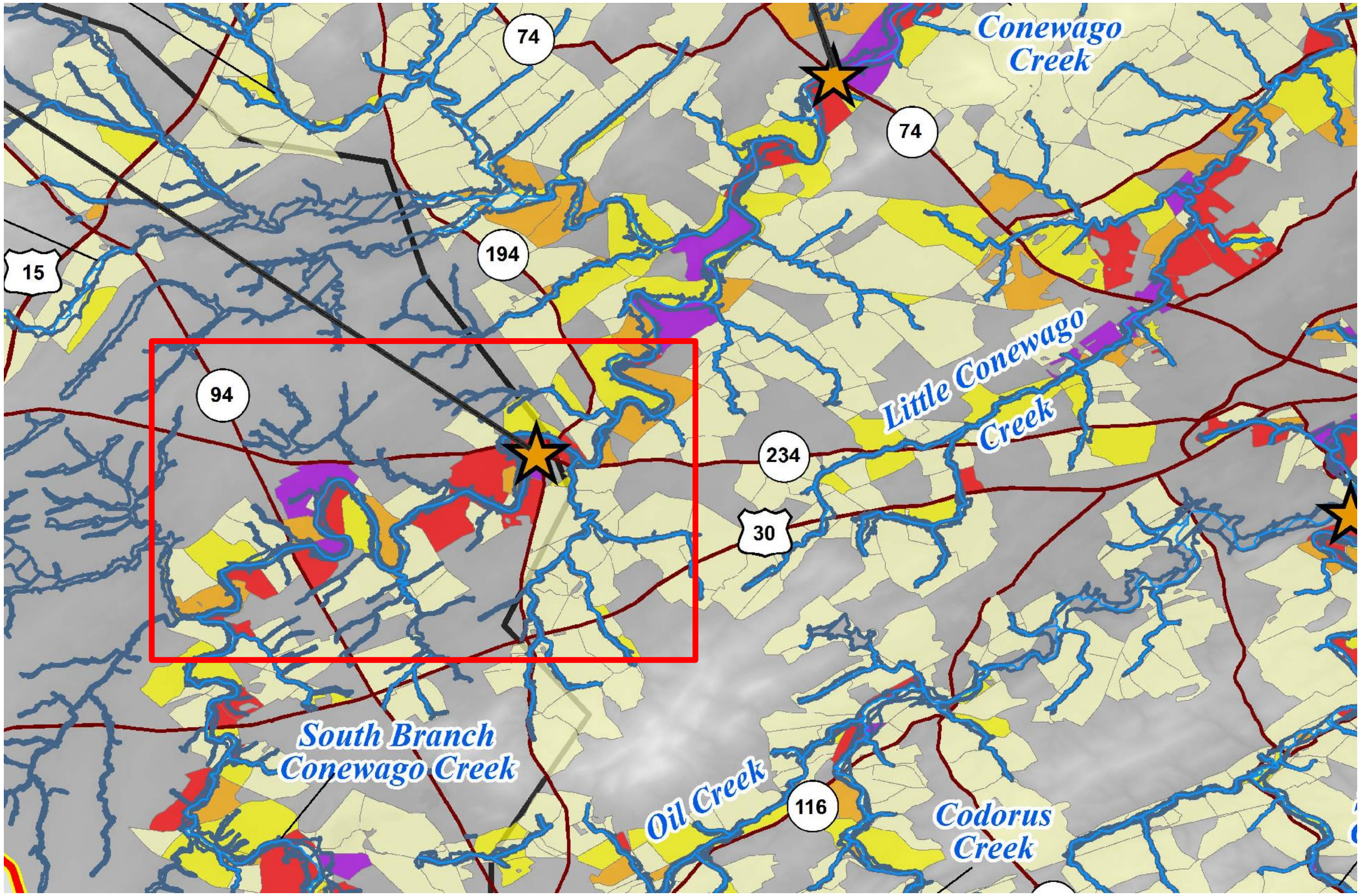
Sub-field profitability based on soils…



Flood risk vulnerability increasing



Losses!?! Tropical Storm Lee – 9/8/2011



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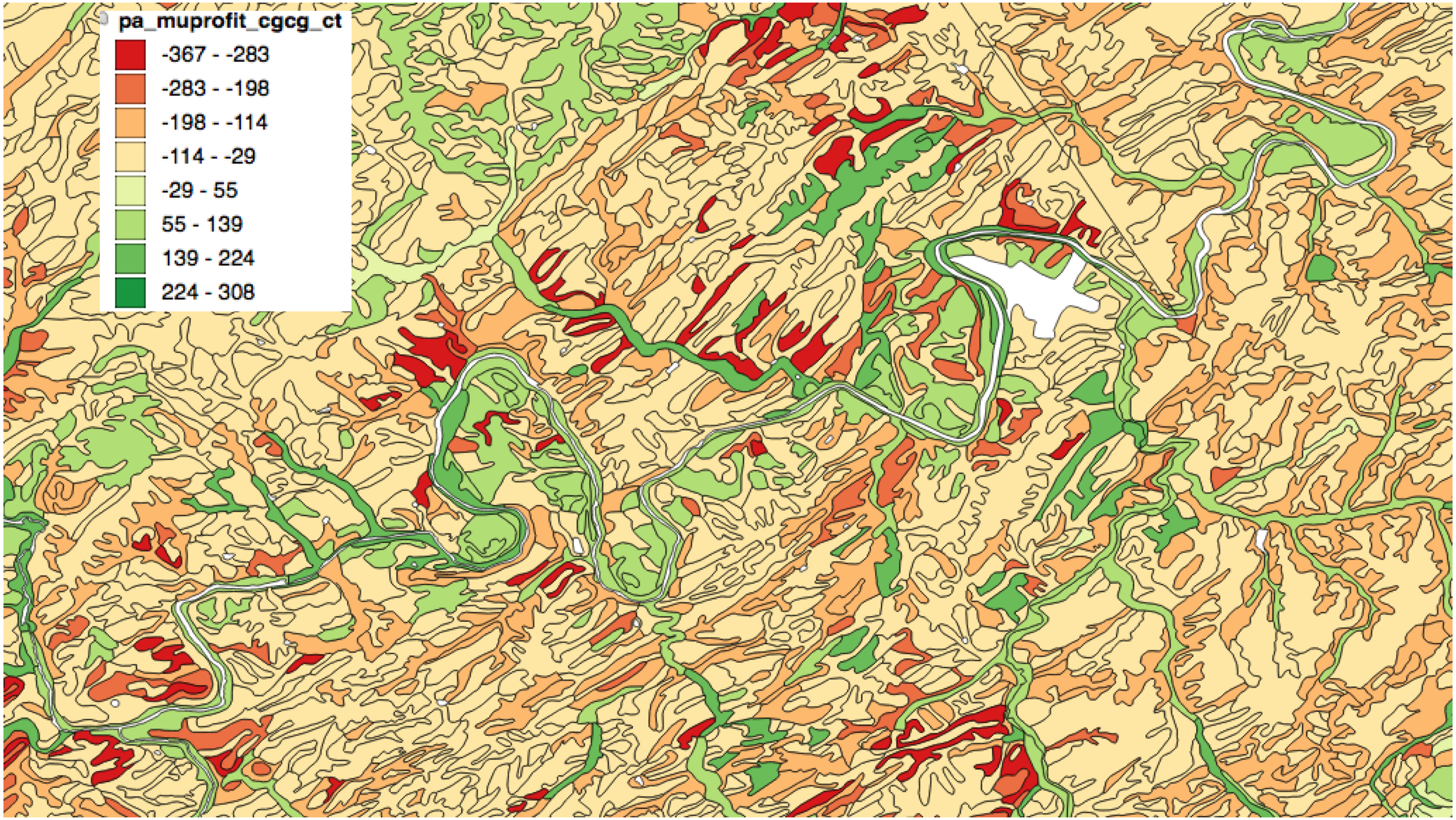
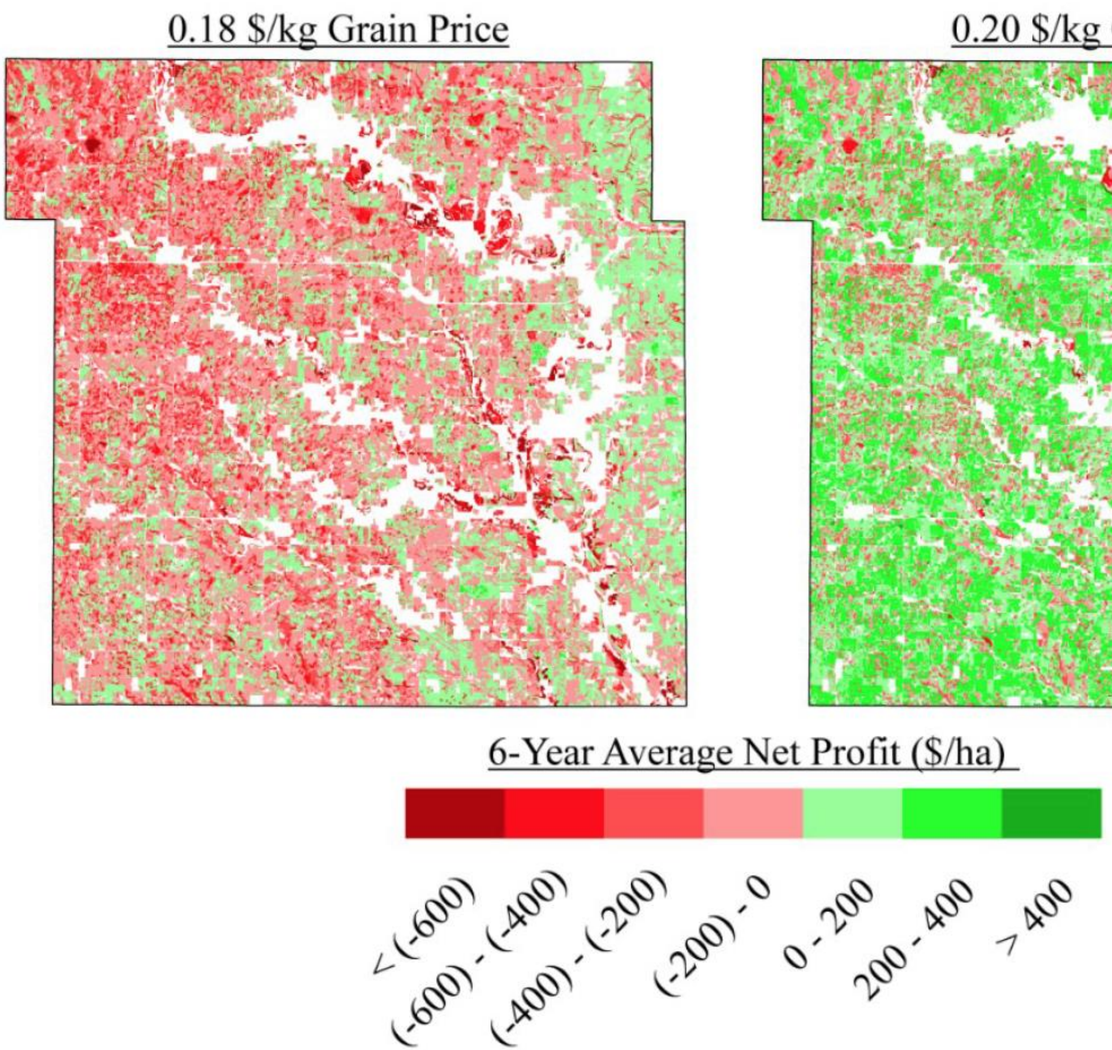
Sub-Field Profitabiity needs Soils plus… hydrology, risk and resilience



Sub-field Profit Analysis in Iowa



Converting the 0.20 $/kg red regions from corn to switchgrass nearly doubles biomass tonnage

Bonner et.al. 2015

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Price Variability

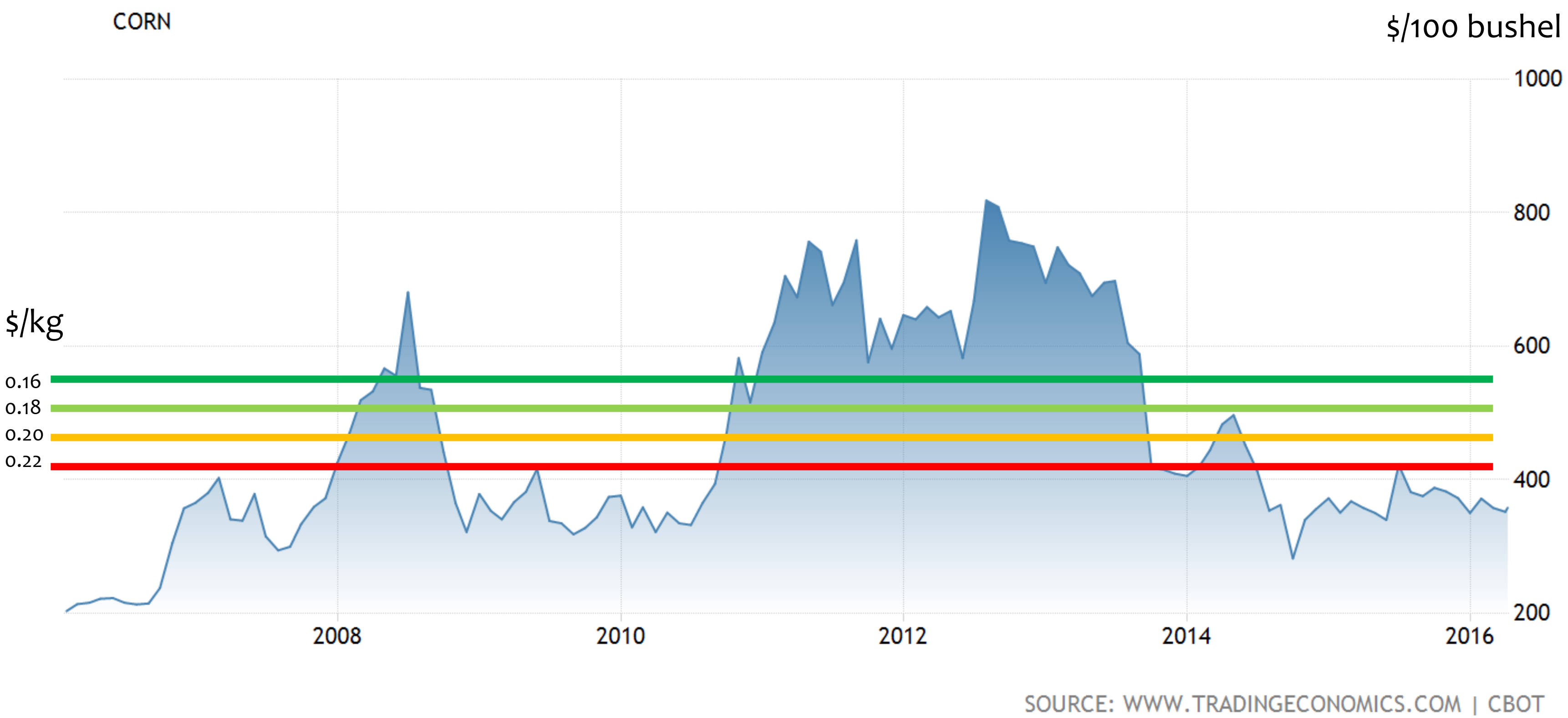
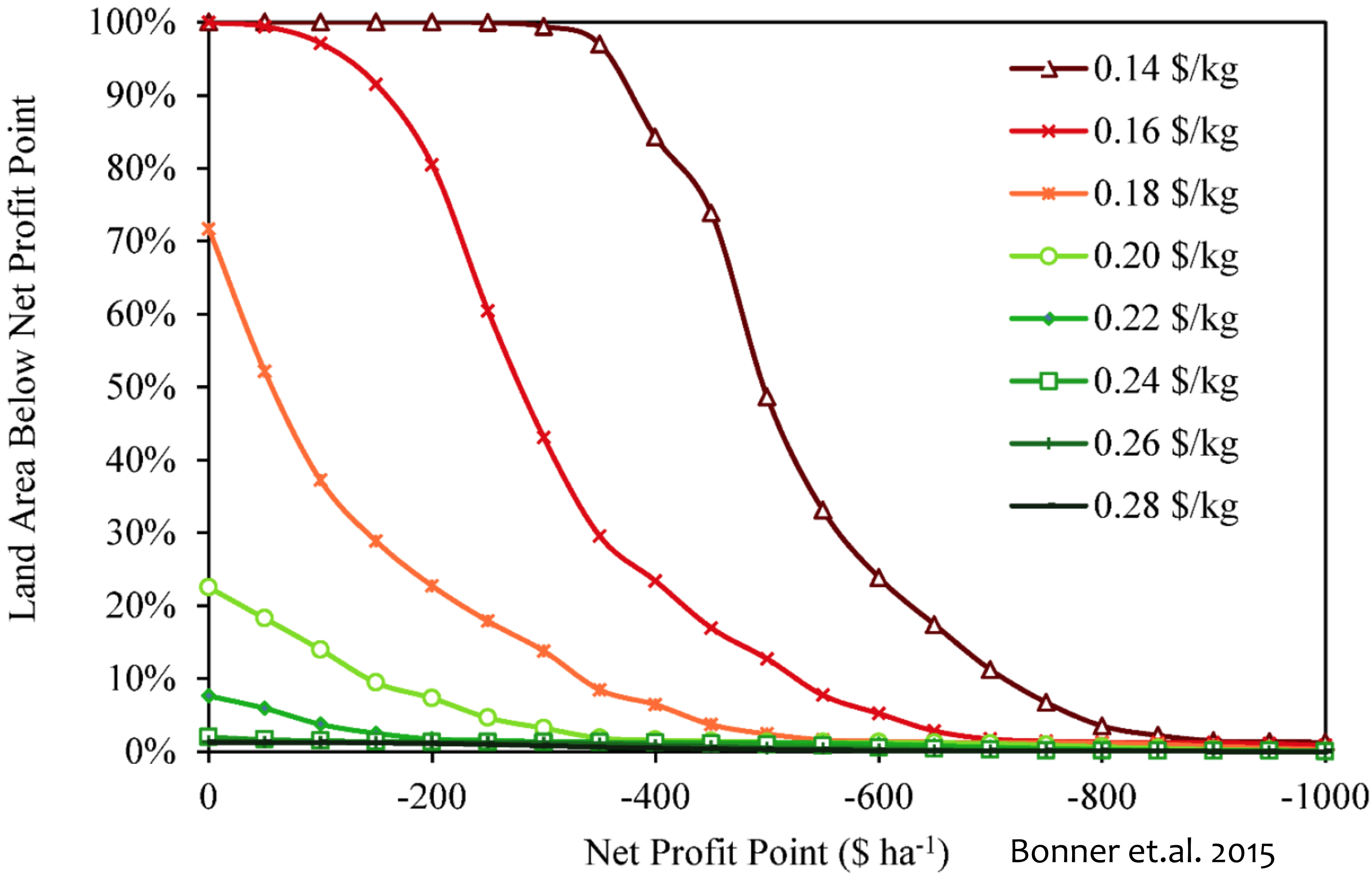


Figure 4. Area within Hardin County, Iowa operating at or below a range of six year average net losses based on varied corn grain price.



Bonner et.al. 2015

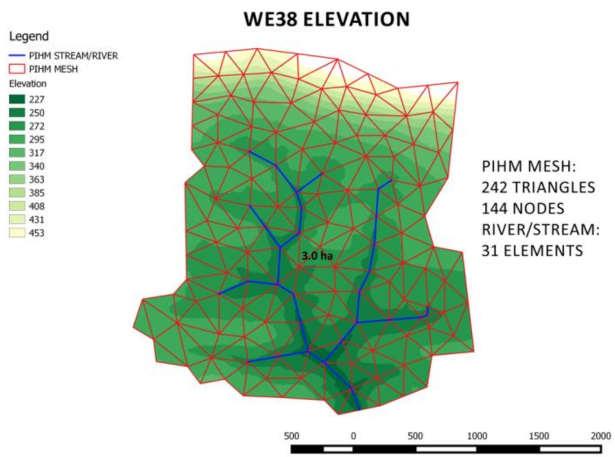
Biomass By the Numbers:

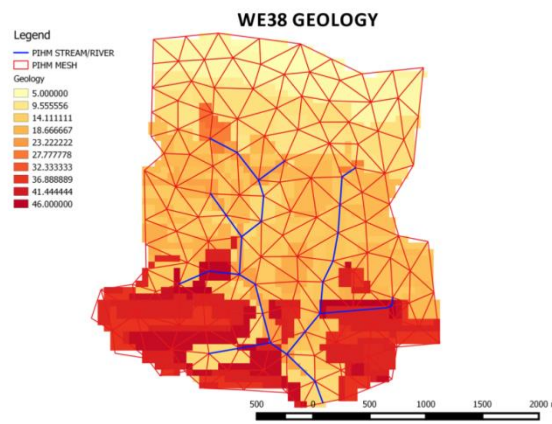
County Level Statistics	Net Profit Decision Point ($\$\cdot ha^{-1}$)						
	0	−100	−200	−300	−400	−600	None
Corn Stover Availability, $Mg\cdot year^{-1}$	182,000	193,000	206,000	213,000	217,000	217,000	217,000
Switchgrass Availability, $Mg\cdot year^{-1}$	250,000	149,000	73,000	29,000	12,000	9,000	0
Total Biomass Availability, $Mg\cdot year^{-1}$	432,000	342,000	278,000	241,000	228,000	226,000	217,000
Mass Fraction Corn Stover	42%	57%	74%	88%	95%	96%	100%
Mass Fraction Switchgrass	58%	43%	26%	12%	5%	4%	0%
Annual Biomass Increase [a]	99%	58%	28%	11%	5%	4%	-
Land Conversion	22%	14%	7%	3%	2%	1%	-
Fields Affected	85%	74%	57%	30%	16%	15%	-
Mean Field Level Area Change [b]	25%	18%	12%	10%	10%	9%	-
Mean Field Level Profit, $\$\cdot ha^{-1}$ [c]	198	174	151	134	127	125	113
Field Level Profit Std.Dev, $\$\cdot ha^{-1}$	92	127	157	175	183	185	205
Profit Variance Between Fields	49%	39%	36%	37%	38%	38%	41%
Profit Variance Within Fields	51%	61%	64%	63%	62%	62%	59%
Reduction in Total Profit Variance	78%	65%	50%	36%	28%	25%	-

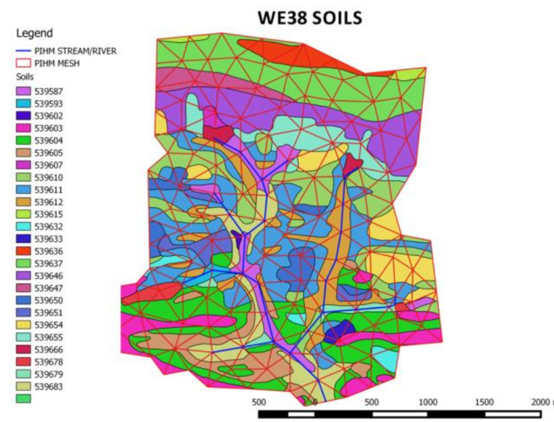
[a] Biomass increase relative to sustainable corn stover availability when no landscape integration is considered;
[b] Mean change in area of only the fields affected by landscape integration at each respective decision point;
[c] All profit calculations are relative to the remaining row crop area of all fields as switchgrass is incorporated.

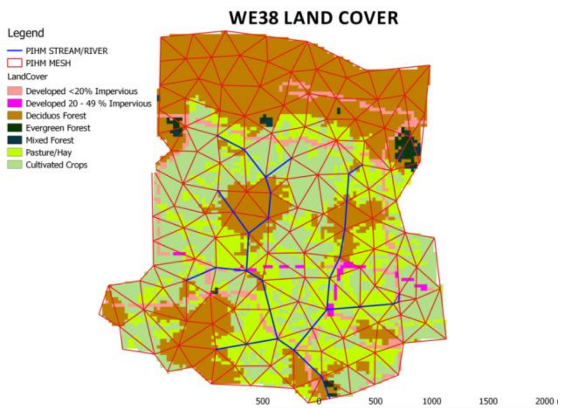
Bonner et.al. 2015

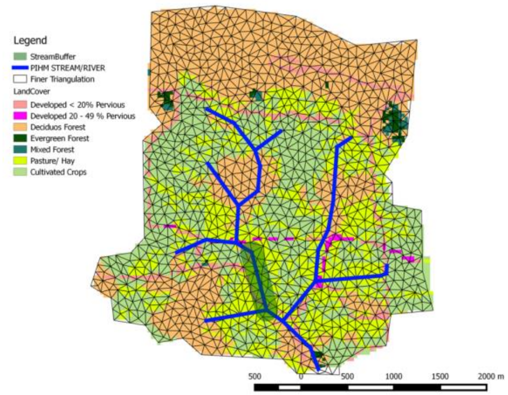
Landscape Agroecosystem Modeling











Outputs: ;

1) Design for Sustainability
2) More profitable farms,
3) Improved water quality,
4) Sustainable biofuels

Build land use scenarios

Montes, Kemanian et al. 2015

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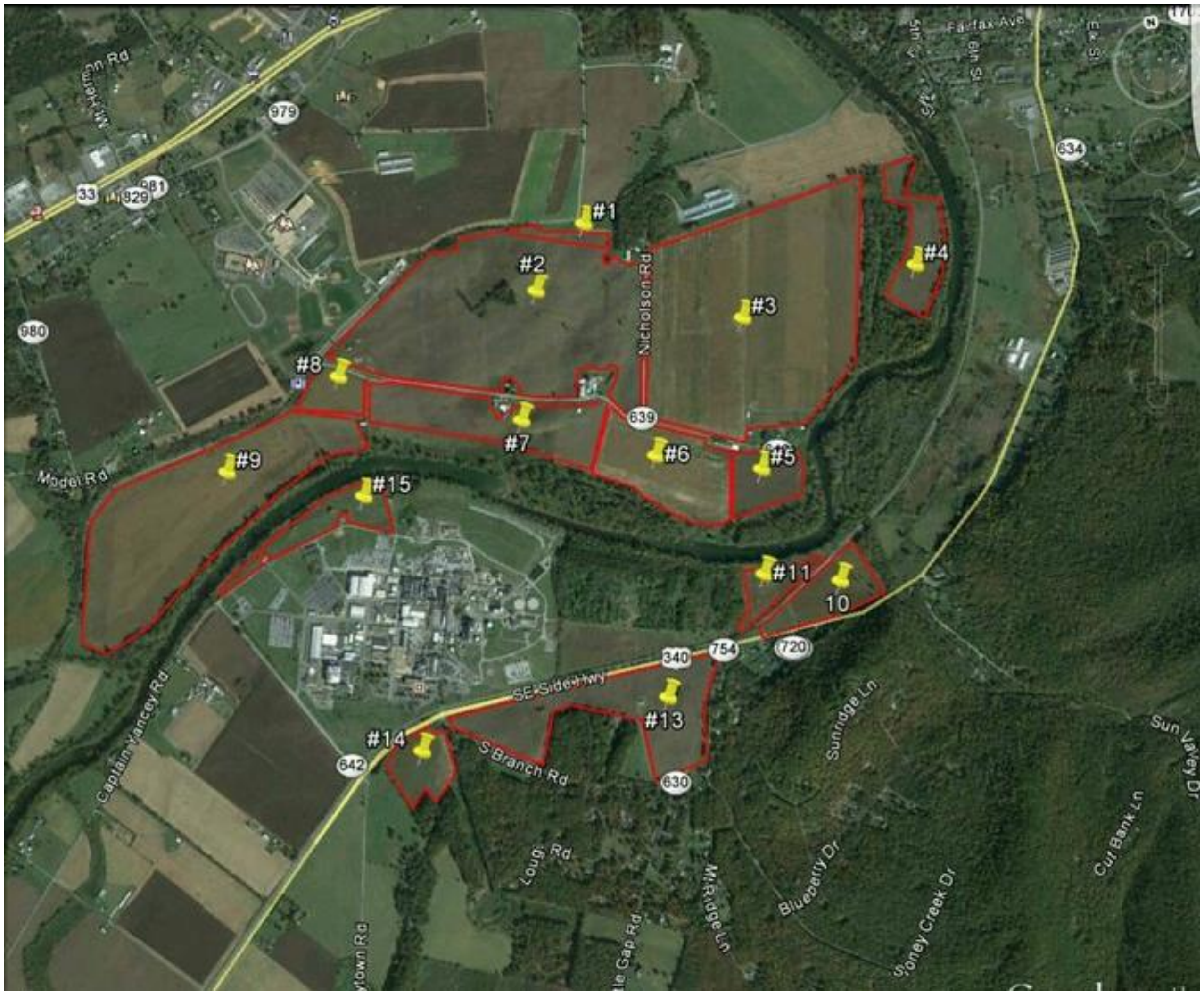
New Patterns on the Landscape



Case #1: Elkton, Va

Owner: Merck

Operator: FDC Enterprises

600 acres switchgrass

Summarizing the Opportunity:

* Perennials and cover crops are recognized as least-cost strategies for improving water quality. Both can also be biofuel feedstocks.
* Farmers currently **assume** that converting land to perennials and cover crops will **reduce** profits.
* Sub-field economic analysis suggests strategic planting of perennials can instead **increase** profits.
* The Bay-State Watershed Implementation Plans include planting hundreds of thousands of acres of cover crops and perennial riparian buffers.
* Managing those areas for biofuels represents an opportunity for not just improving water quality, but improving farm profitability, rural economic activity, and sustainable energy for the region.

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