Aviation Biofuels and the Chesapeake Watershed: Coupling Sustainable Energy with Sustainable Agriculture

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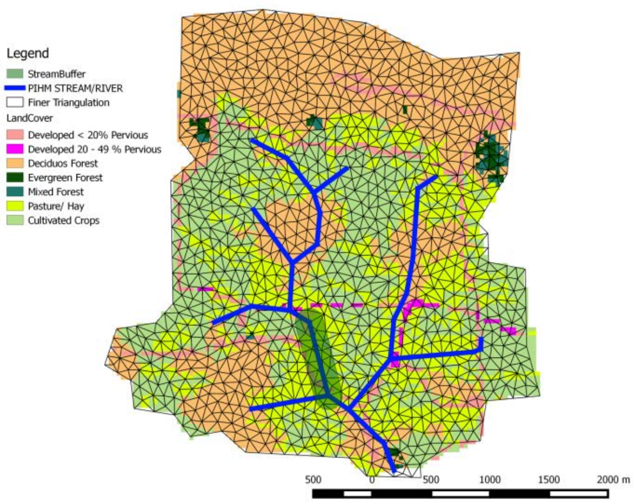

ASCENT AVIATION SUSTAINABILITY CENTER

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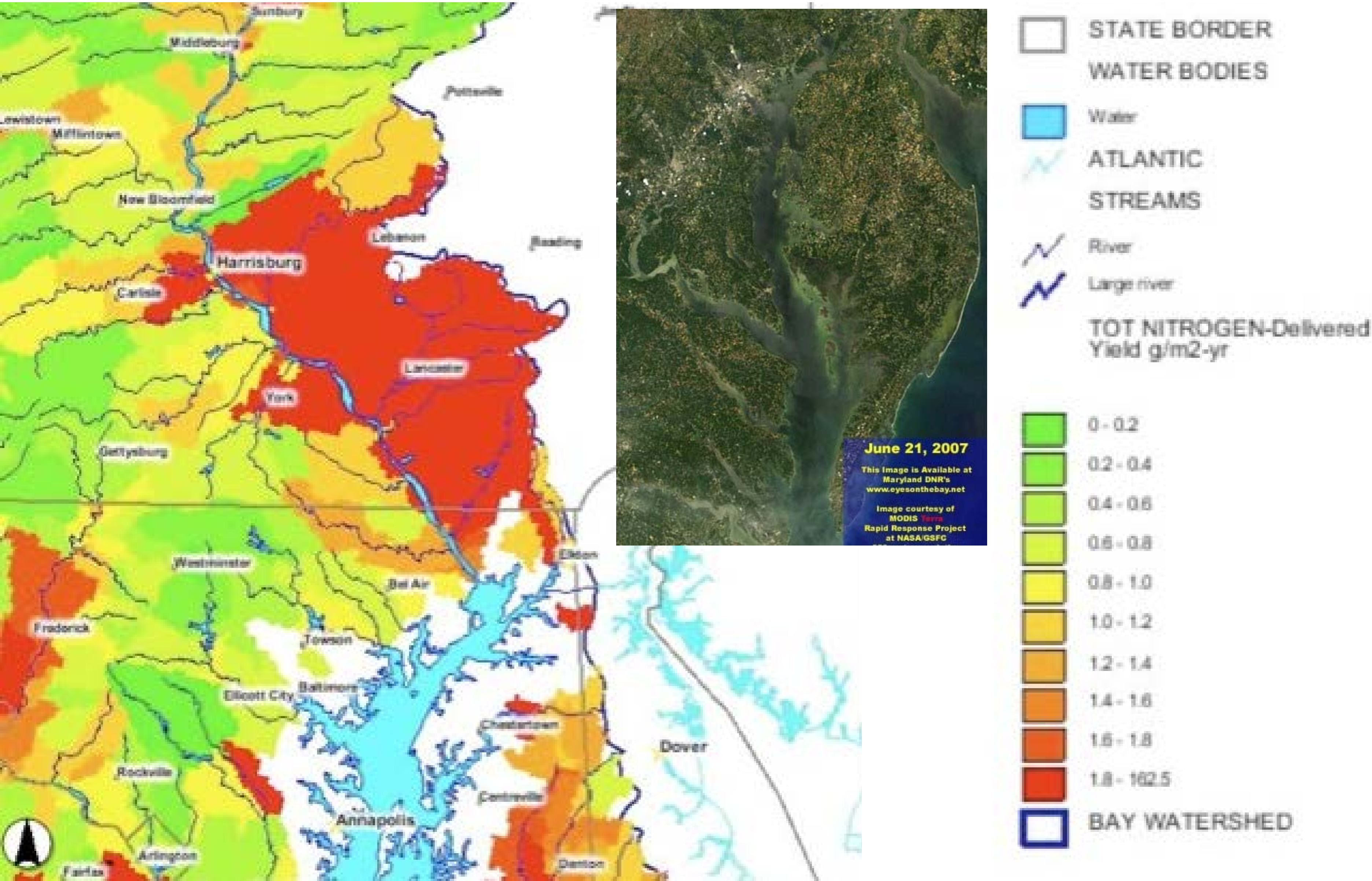
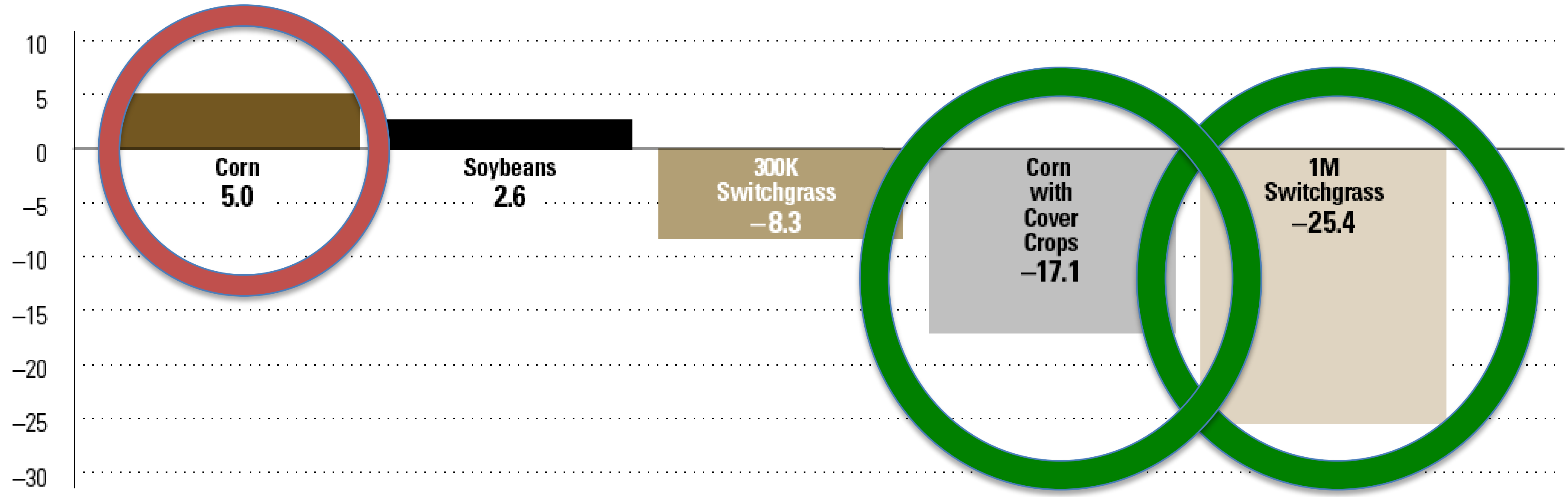
Nutrient Loading in the Chesapeake



Biofuels and water quality: Blessing or Bane?

Maximum Nitrogen Load Changes for Biofuels

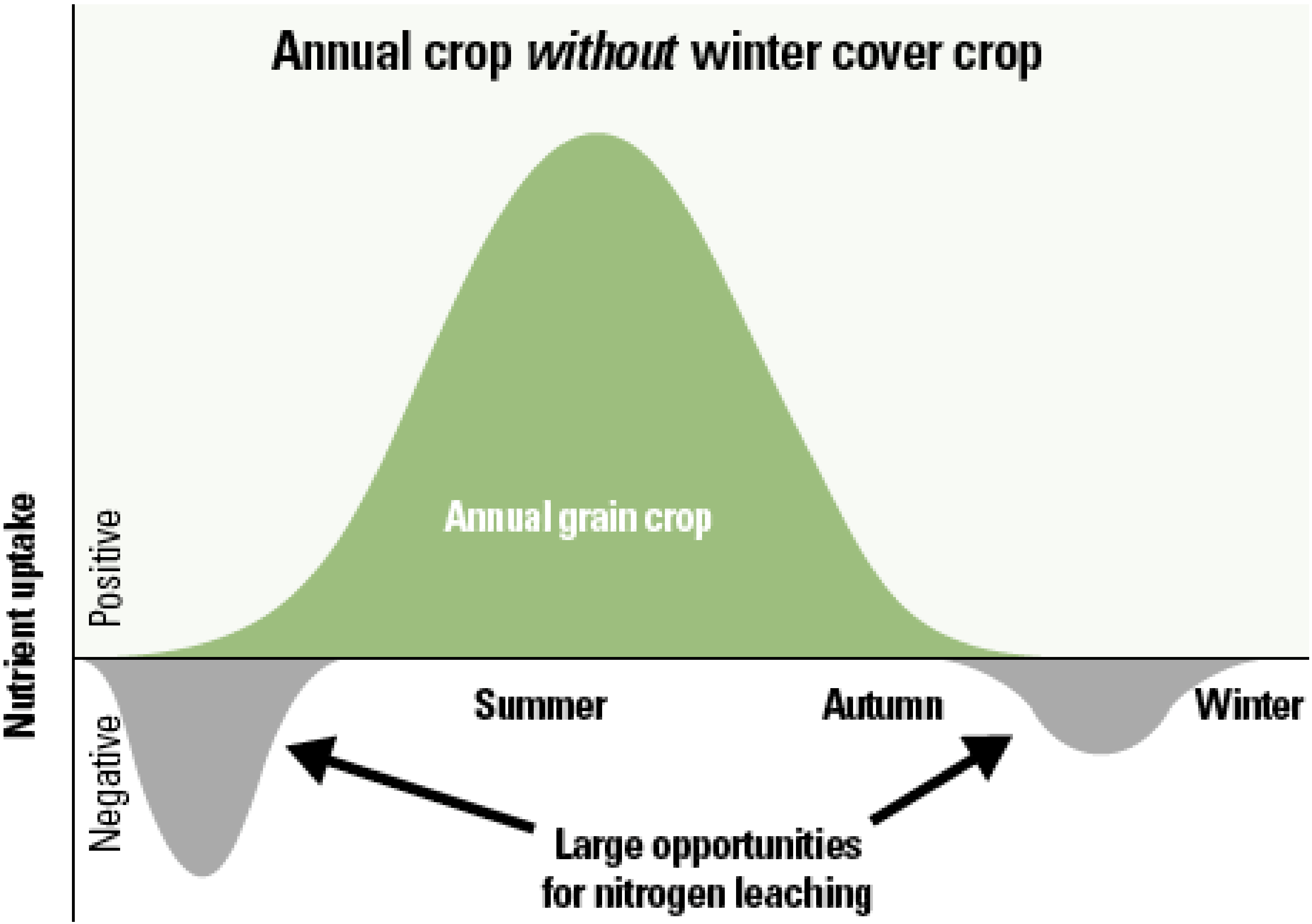
Millions of pounds per year of nitrogen delivered from the Chesapeake Bay watershed to the Bay under five modeling scenarios.



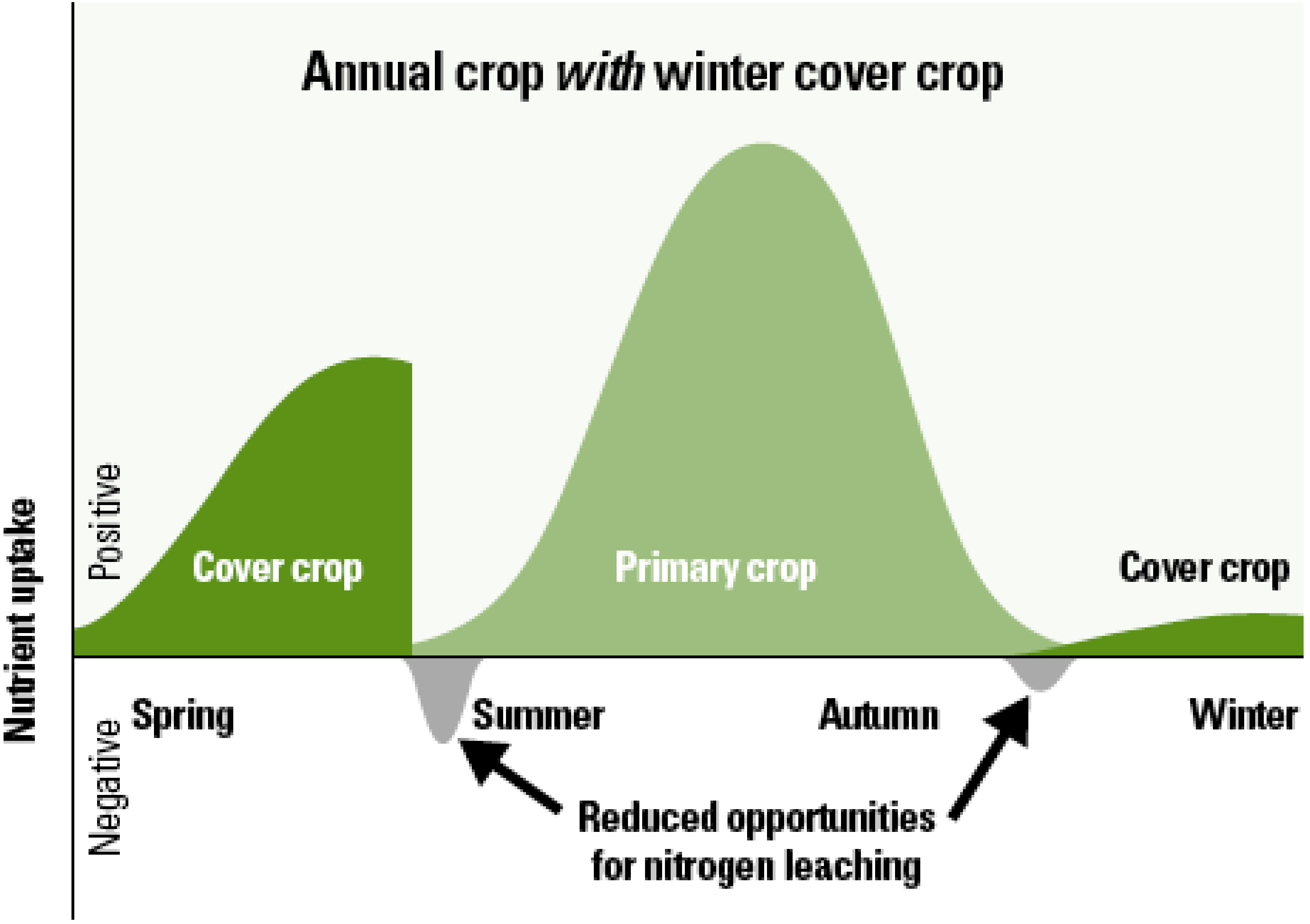
Assumptions for Alternative Scenarios:

- **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



Source: Andy Heggensaeller, Iowa State University



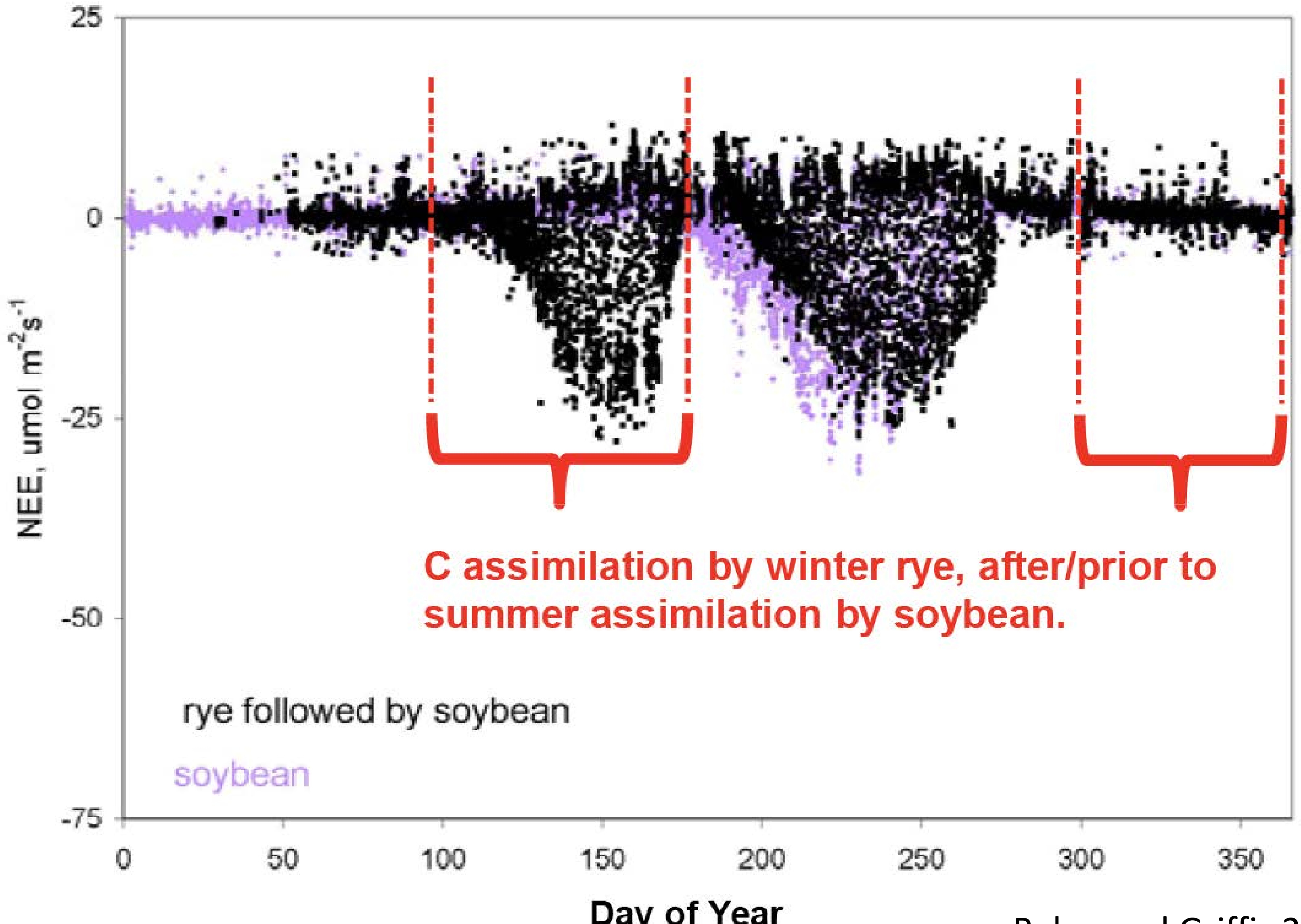
SOURCE: Andrew H. Heggenstaller, Iowa State University

Why Winter Energy Crops?

- Complement summer annuals
- Available equipment and experience
- Affordable, short-term financing
- Scale-up can be very fast

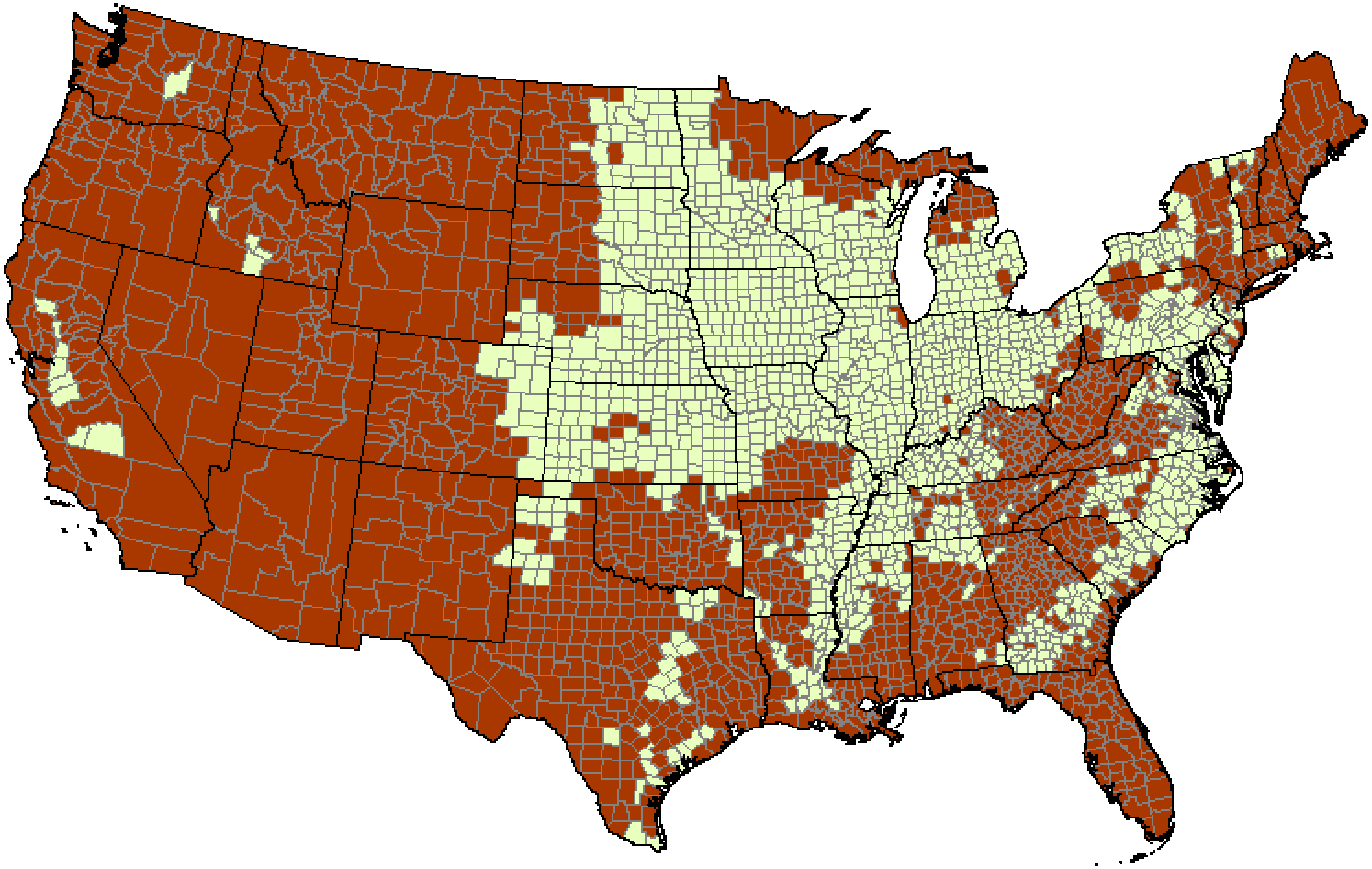
Bonus #3: Rye increases carbon sequestration

Decreases Net Ecosystem Exchange (NEE) of CO_2



Baker and Griffis 2009

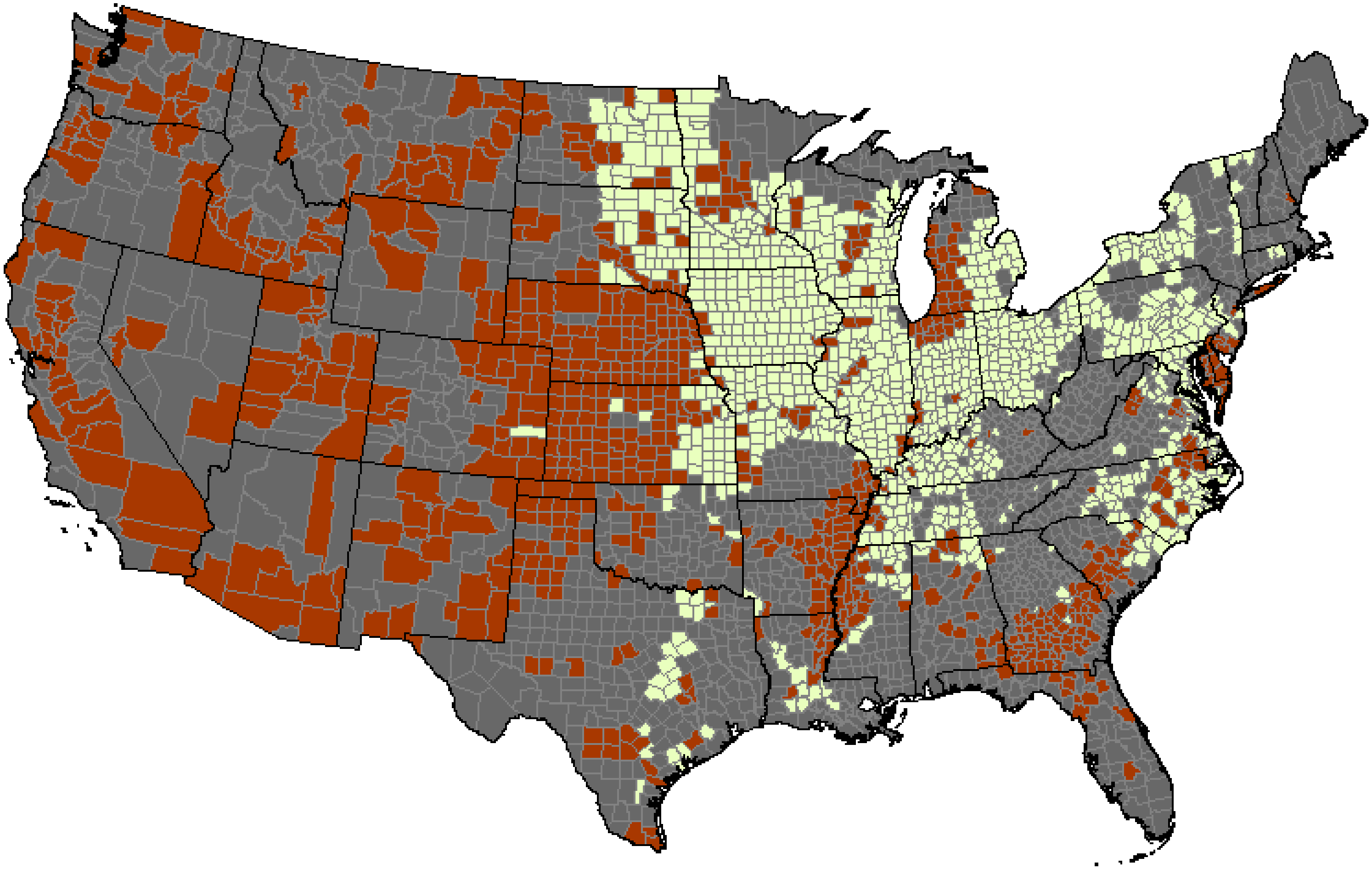
Rule 1: Focus on Corn and Soybeans



Red: Counties where less than 2% of total county area is producing corn or soybeans

Feyereisen et al. 2013

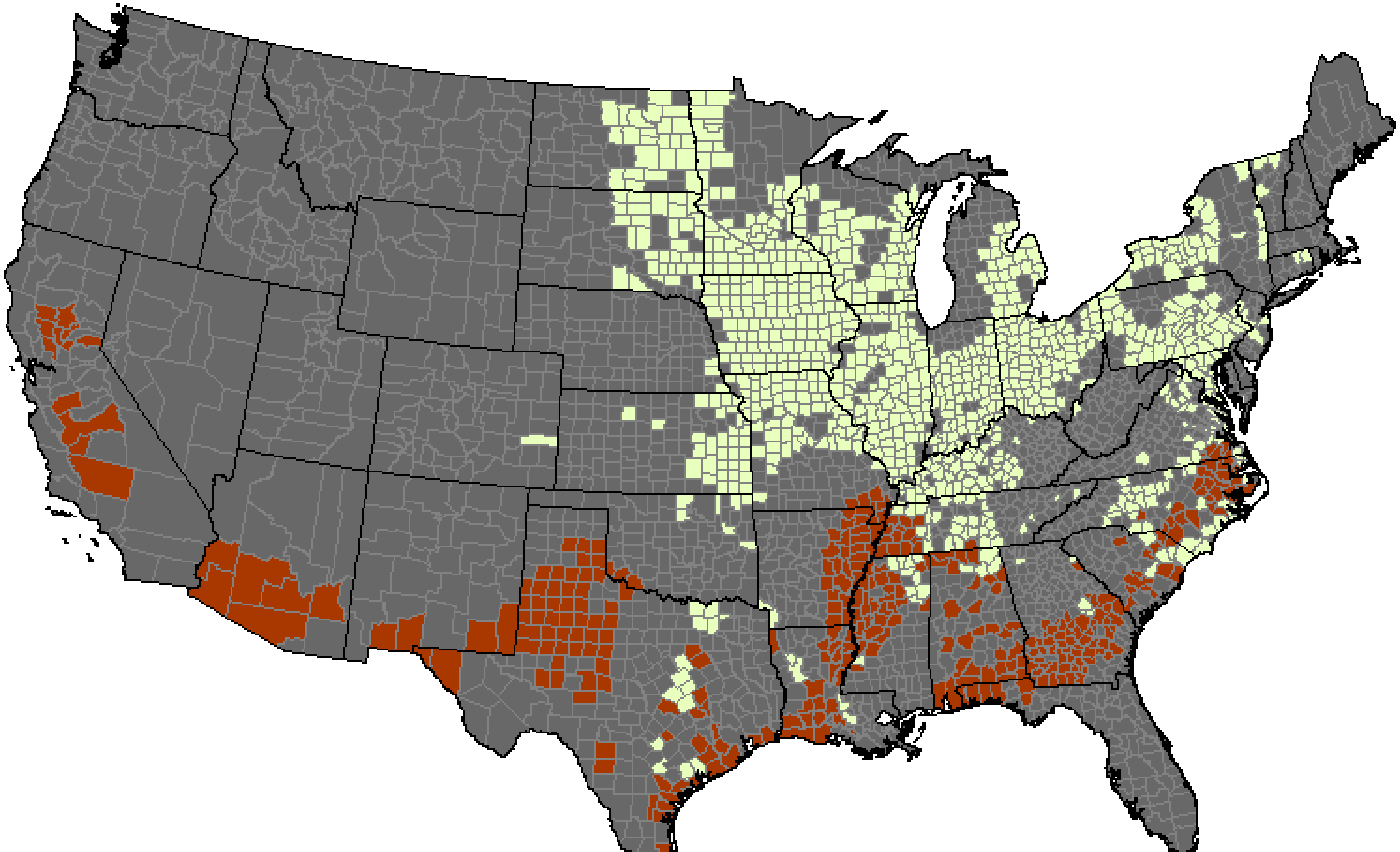
Rule 2: Plant where winter rains are plentiful



Red: Counties where greater than 5% of corn acreage is irrigated

Feyereisen et al. 2013

Rule 3: Don't compete with other winter crops

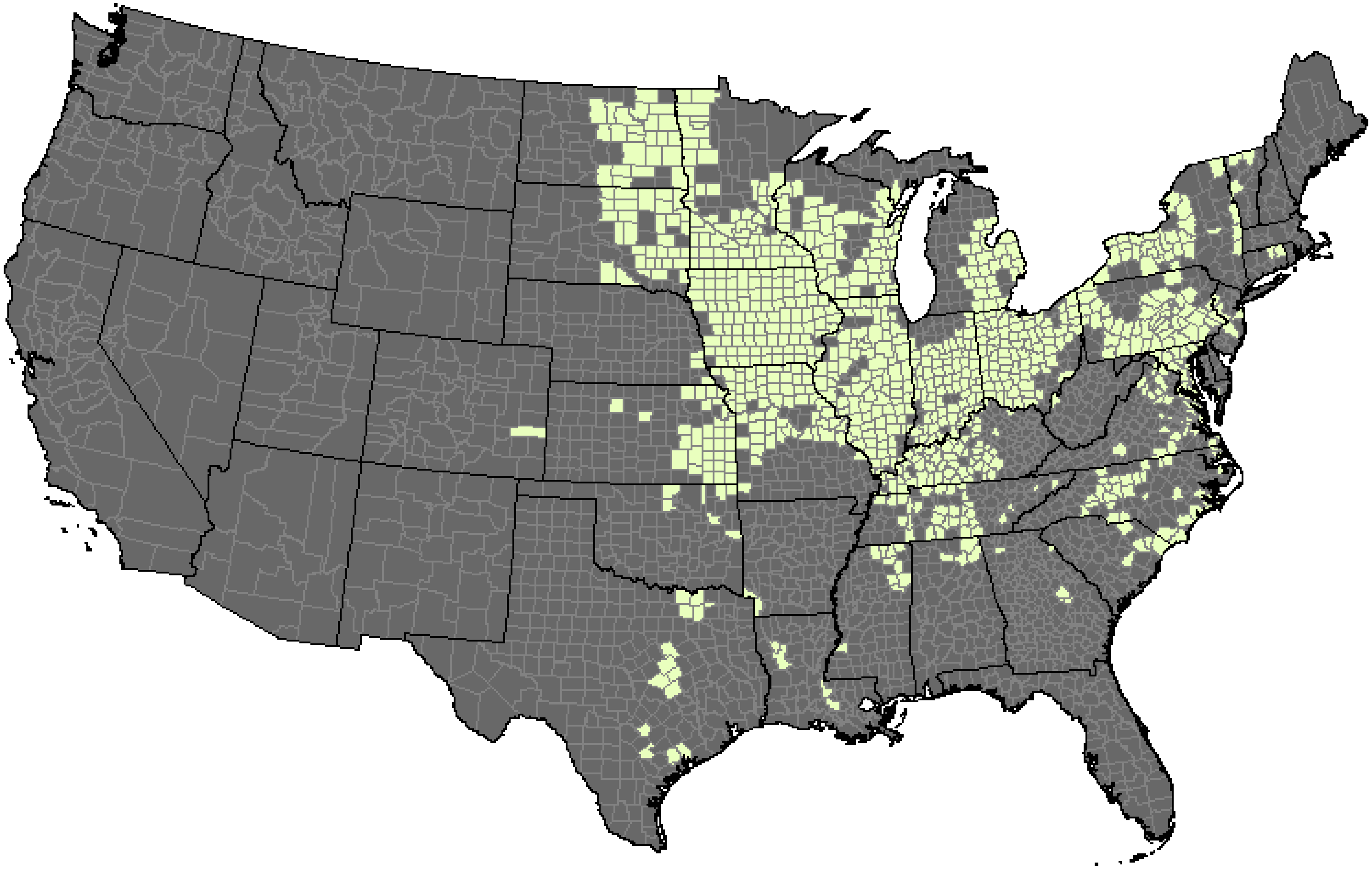


Red: Counties where greater than 10% of total cropland is producing rice or cotton.

Yellow: Existing acres of winter wheat and barley also excluded.

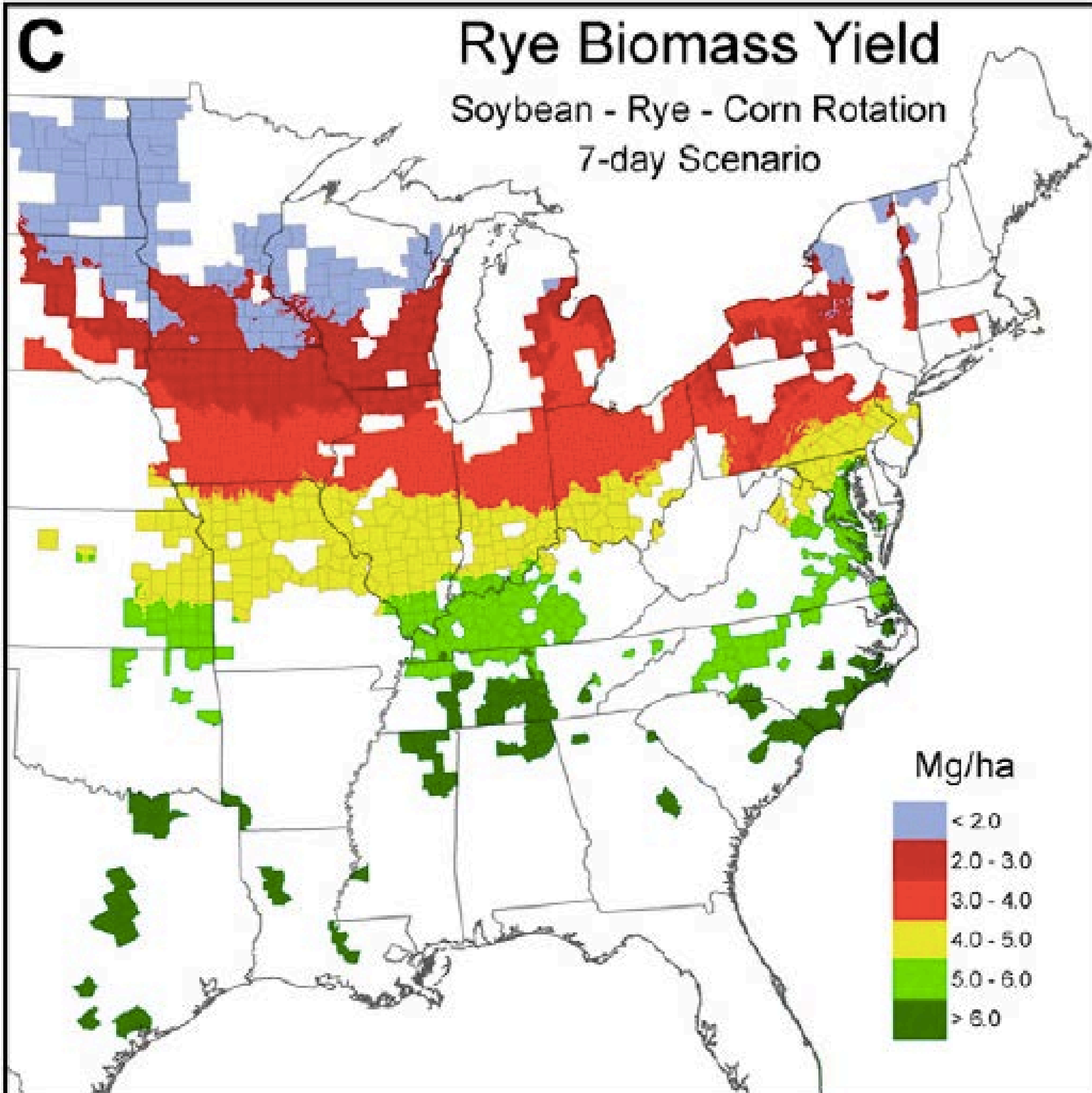
Feyereisen et al. 2013

What's left? Available Winter Cropland…

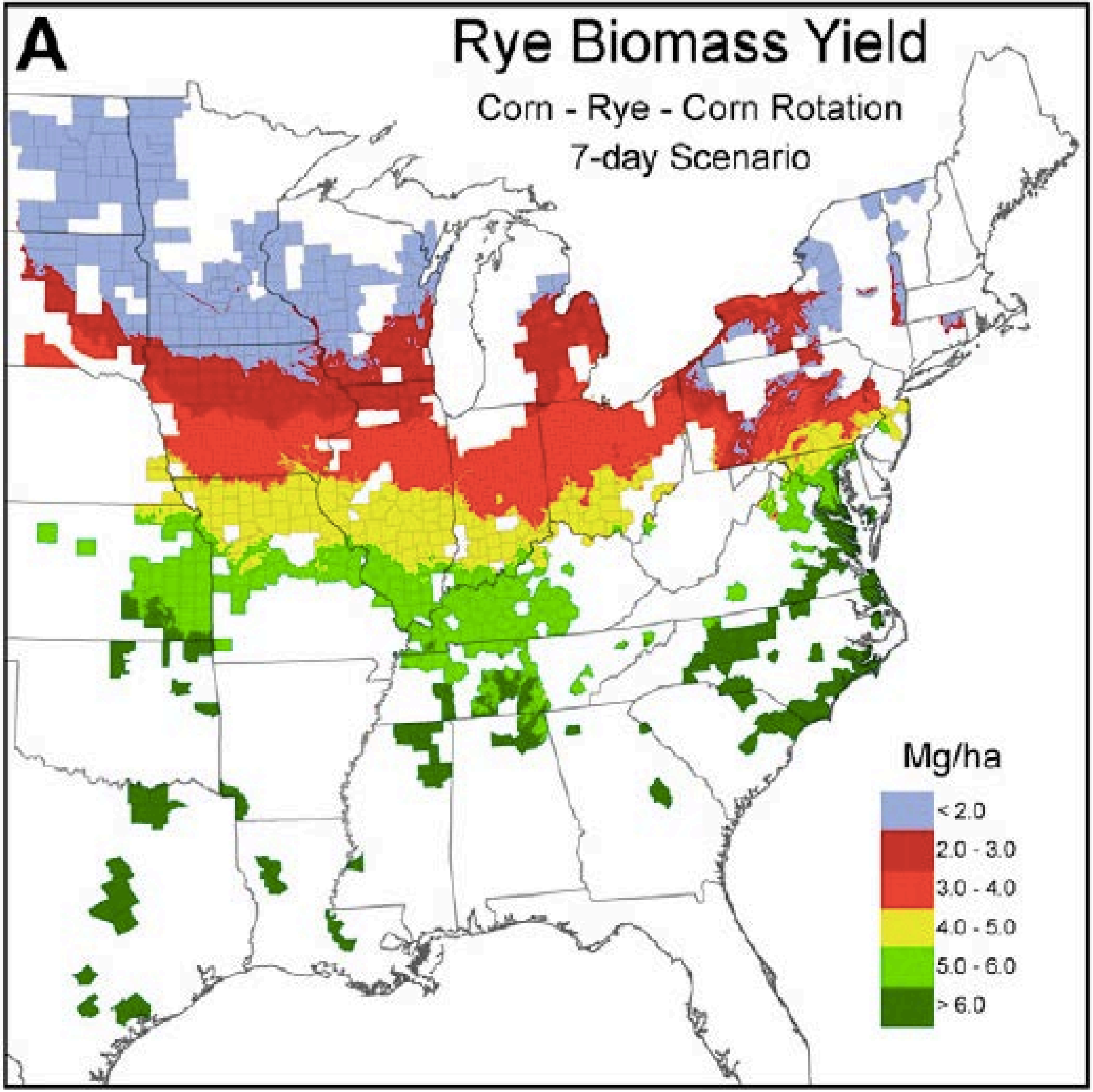


Gray: Counties excluded from consideration for winter rye production

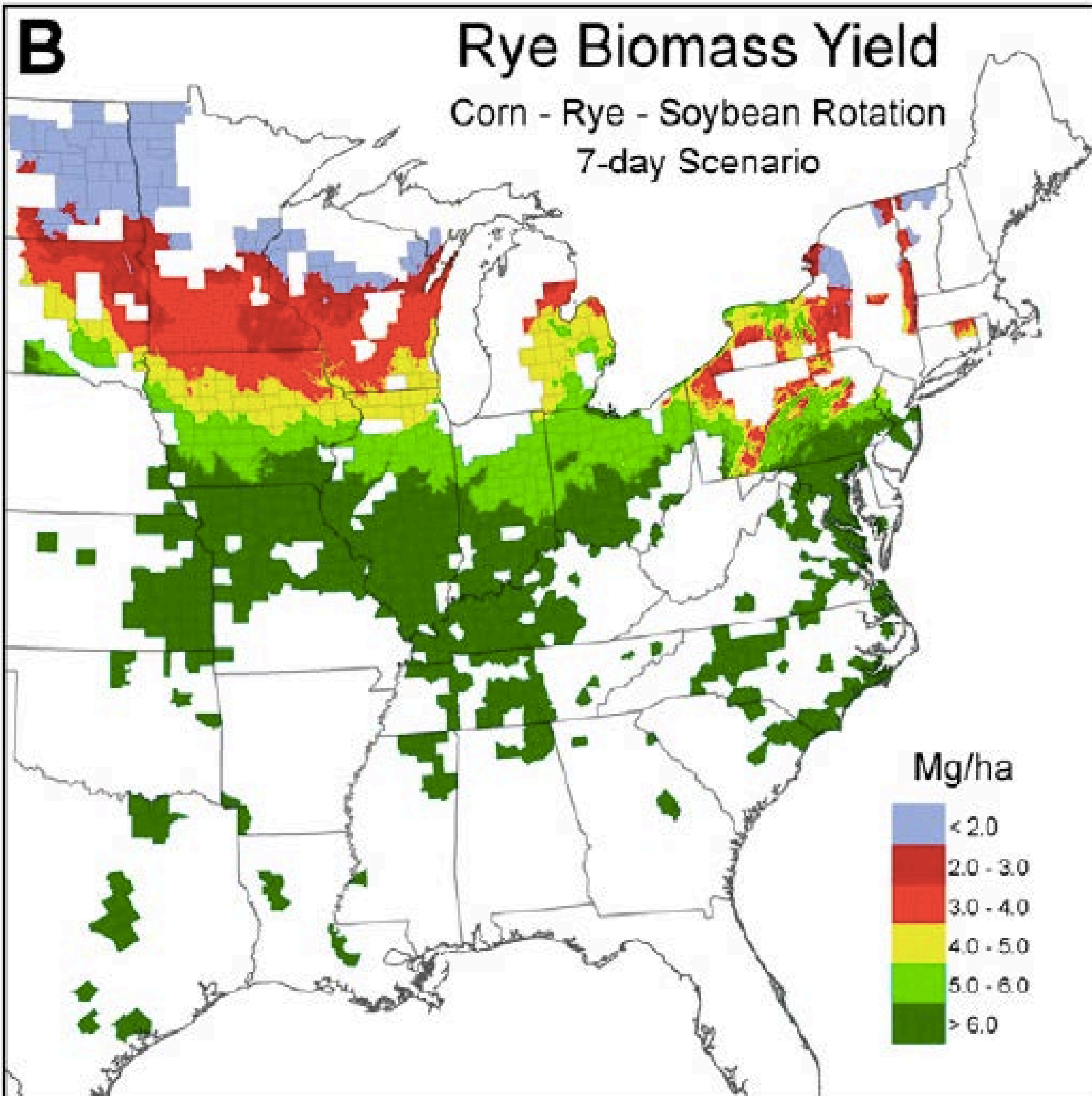
Feyereisen et al. 2013



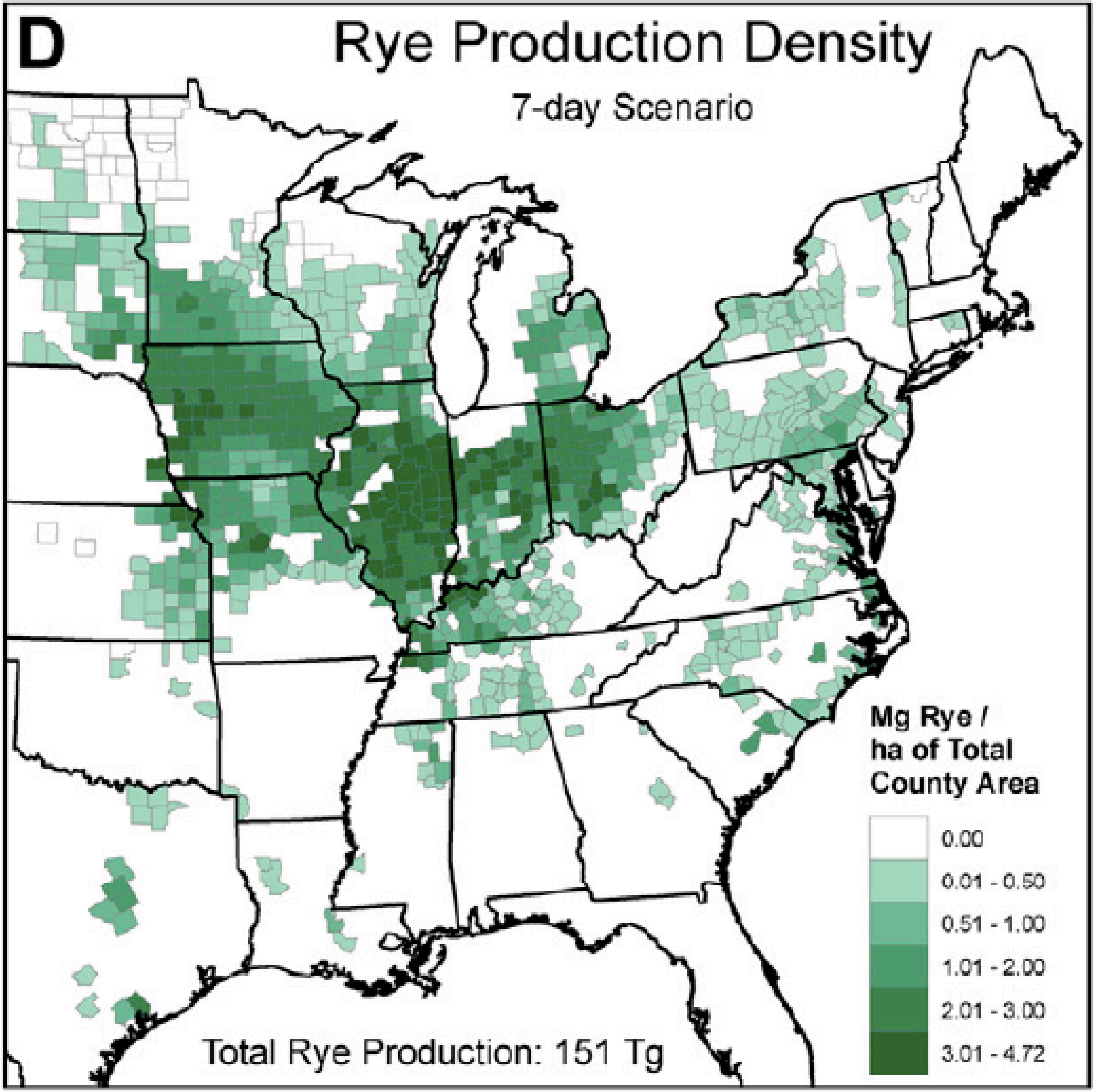
Feyereisen et al. 2013



Feyereisen et al. 2013



Feyereisen et al. 2013



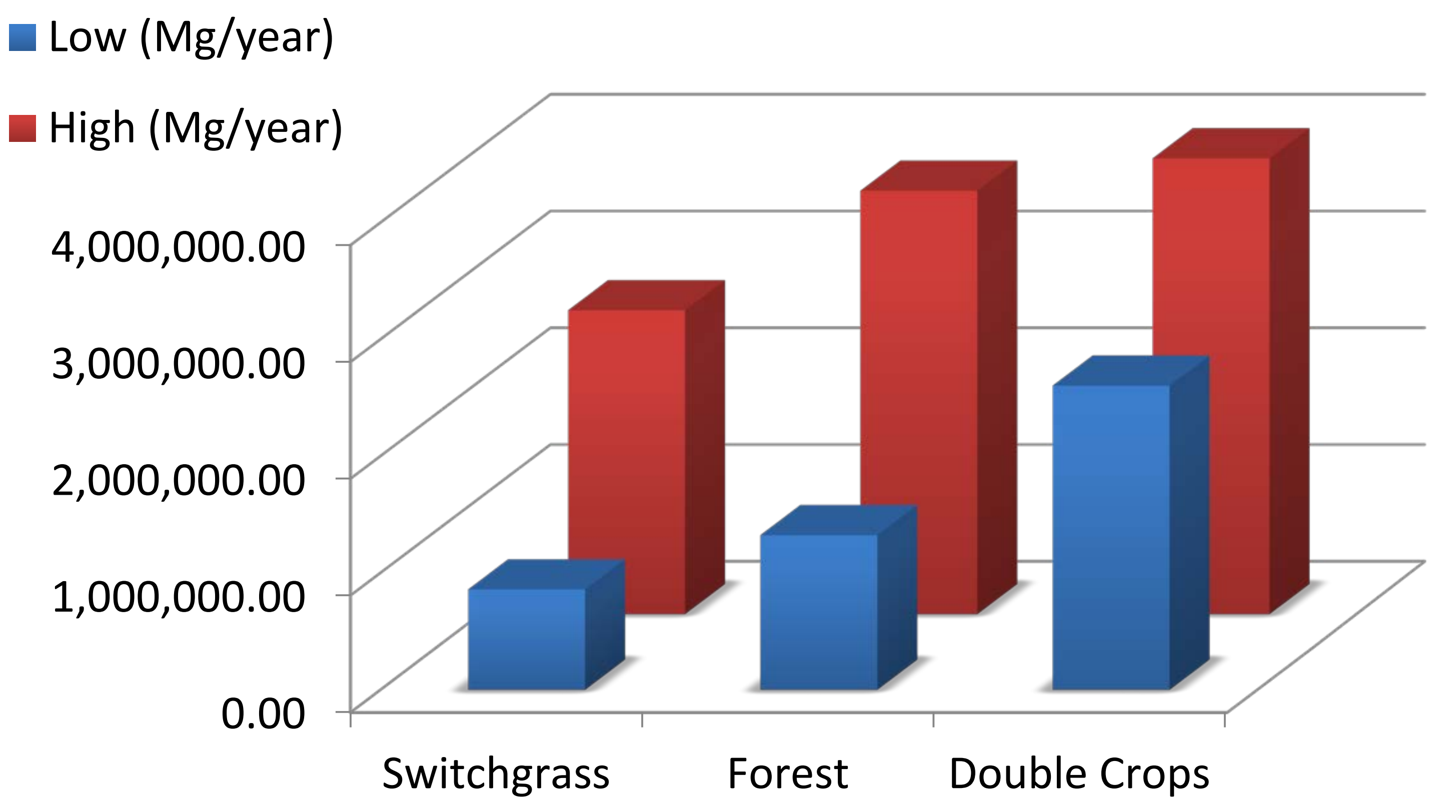
Feyereisen et al. 2013

A Triple Bottom Line

110 - 160 million dry tons/year of winter crops =

- People: Off-season jobs in rural communities.
- Planet: Multiple carbon reduction components, improved soil and water quality, other ecosystem services.
- Profit: More income for farmers, local businesses, and biorefineries.

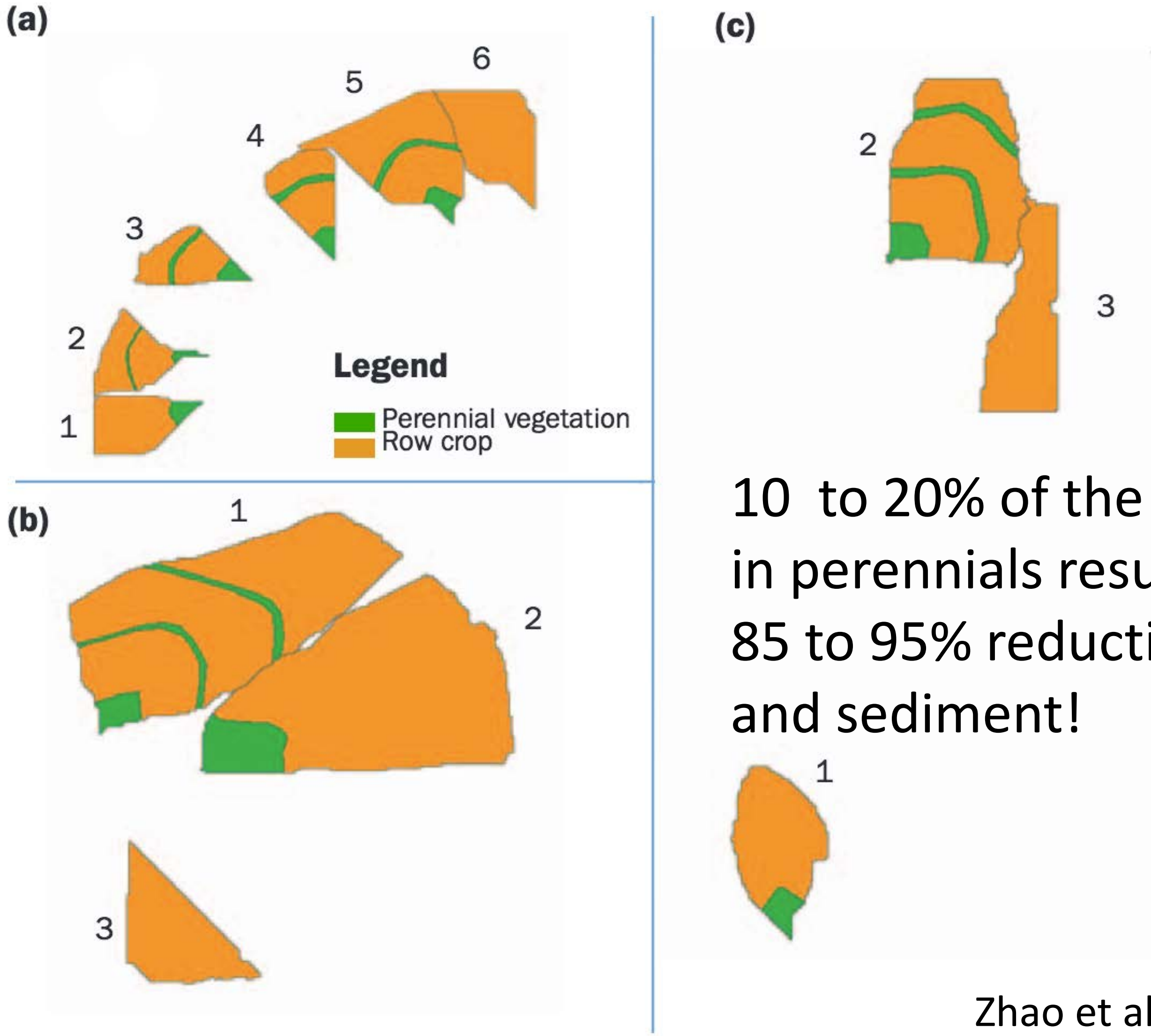
Bonus #2: Familiarity drives Adoption



Chesapeake Biomass Potential

Chesapeake Bay Commission, 2010

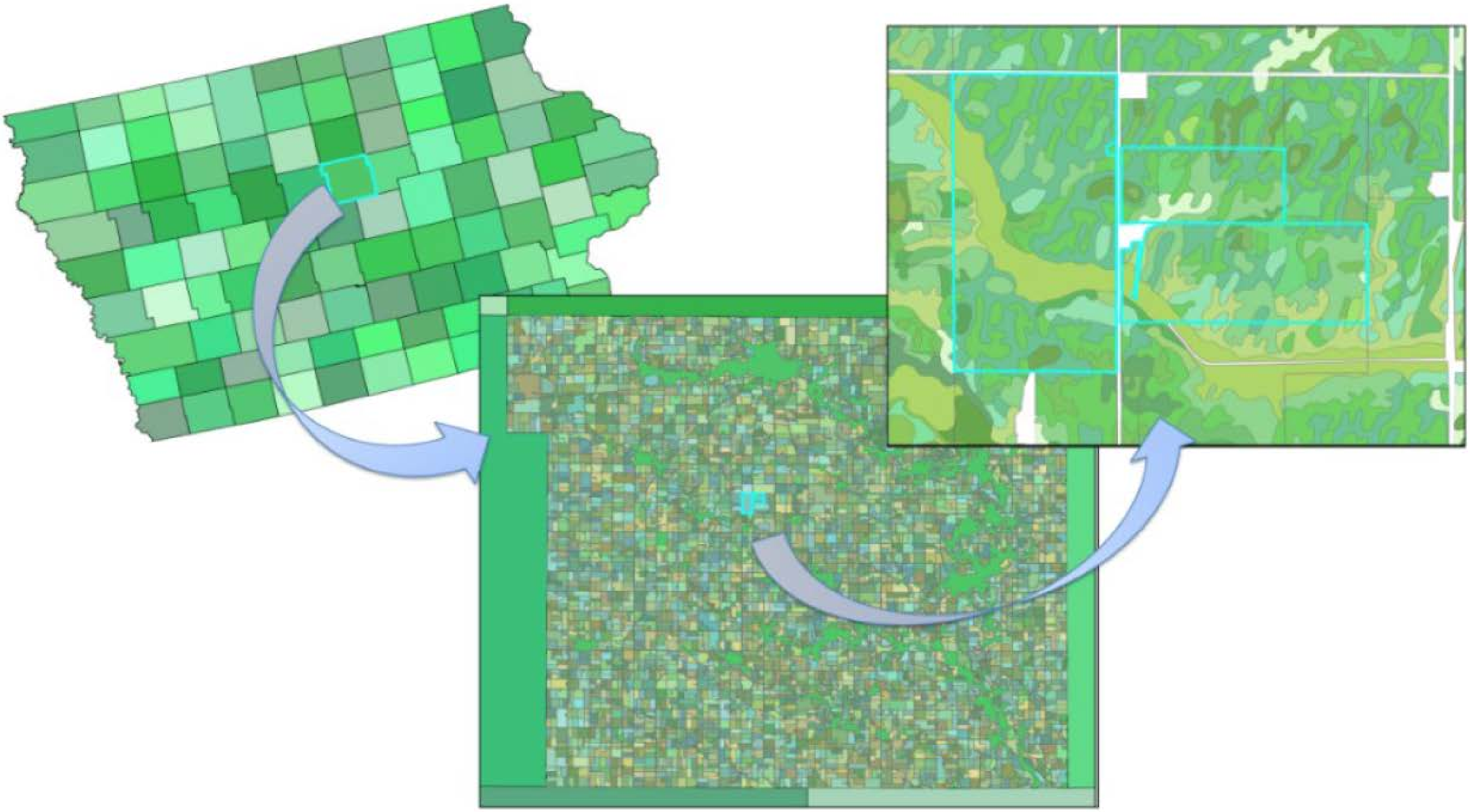
Landscape Design



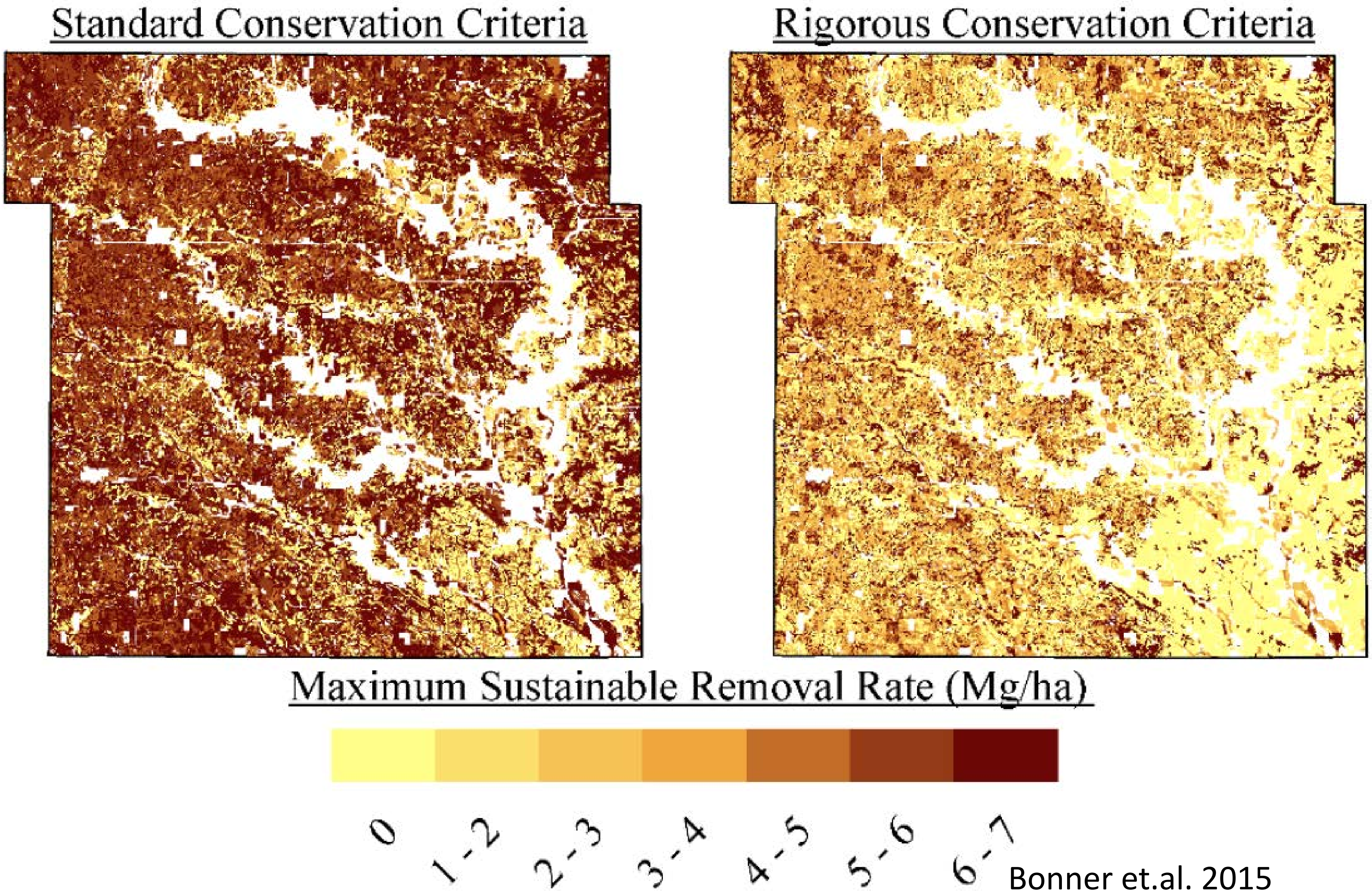
10 to 20% of the landscape in perennials results in
85 to 95% reductions in N, P and sediment!

Zhao et al. 2014

Landscape Agro-economic Modeling: Iowa Example



Bonner et.al. 2015



Bonner et.al. 2015

Sub-field Profit Analysis

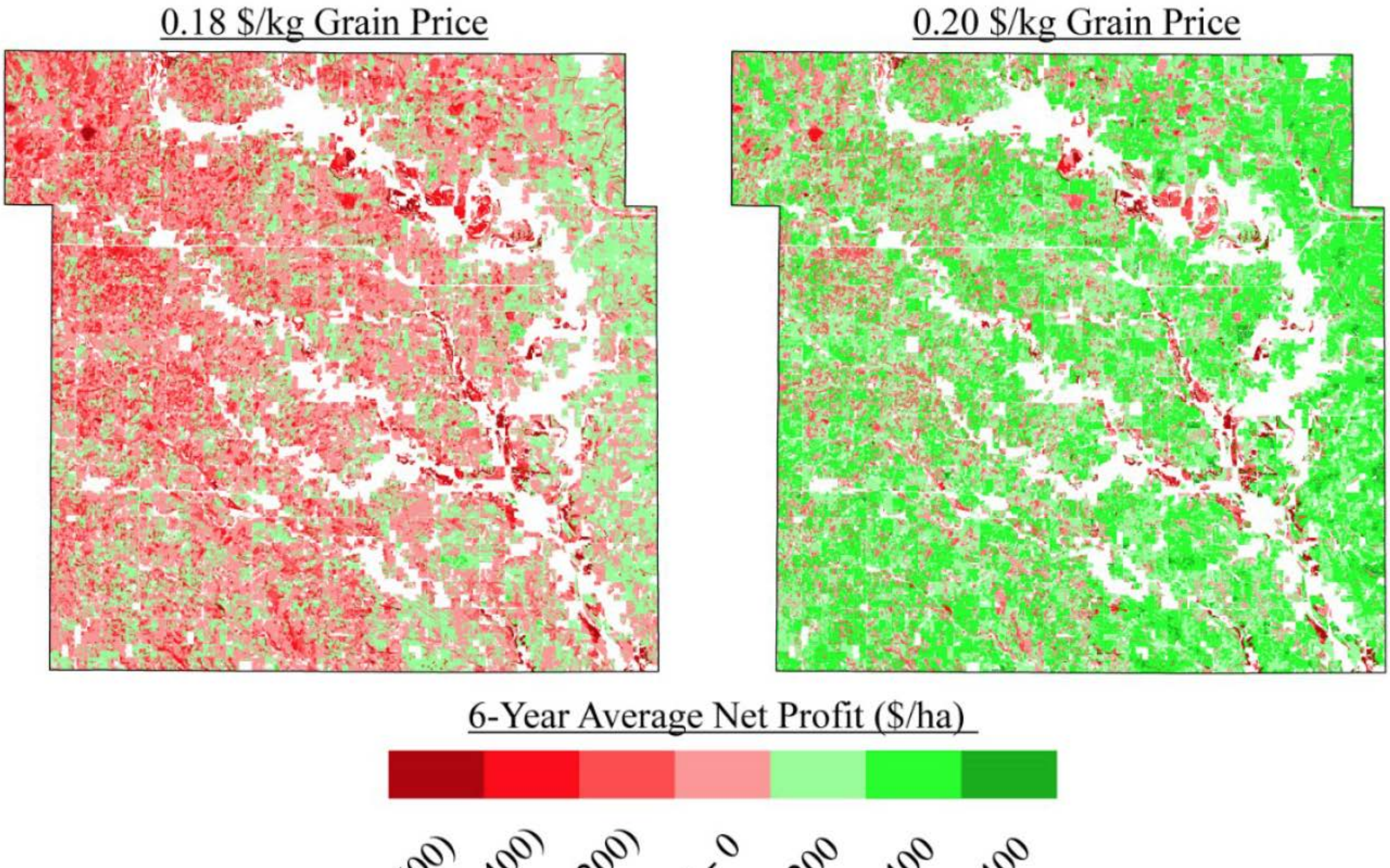
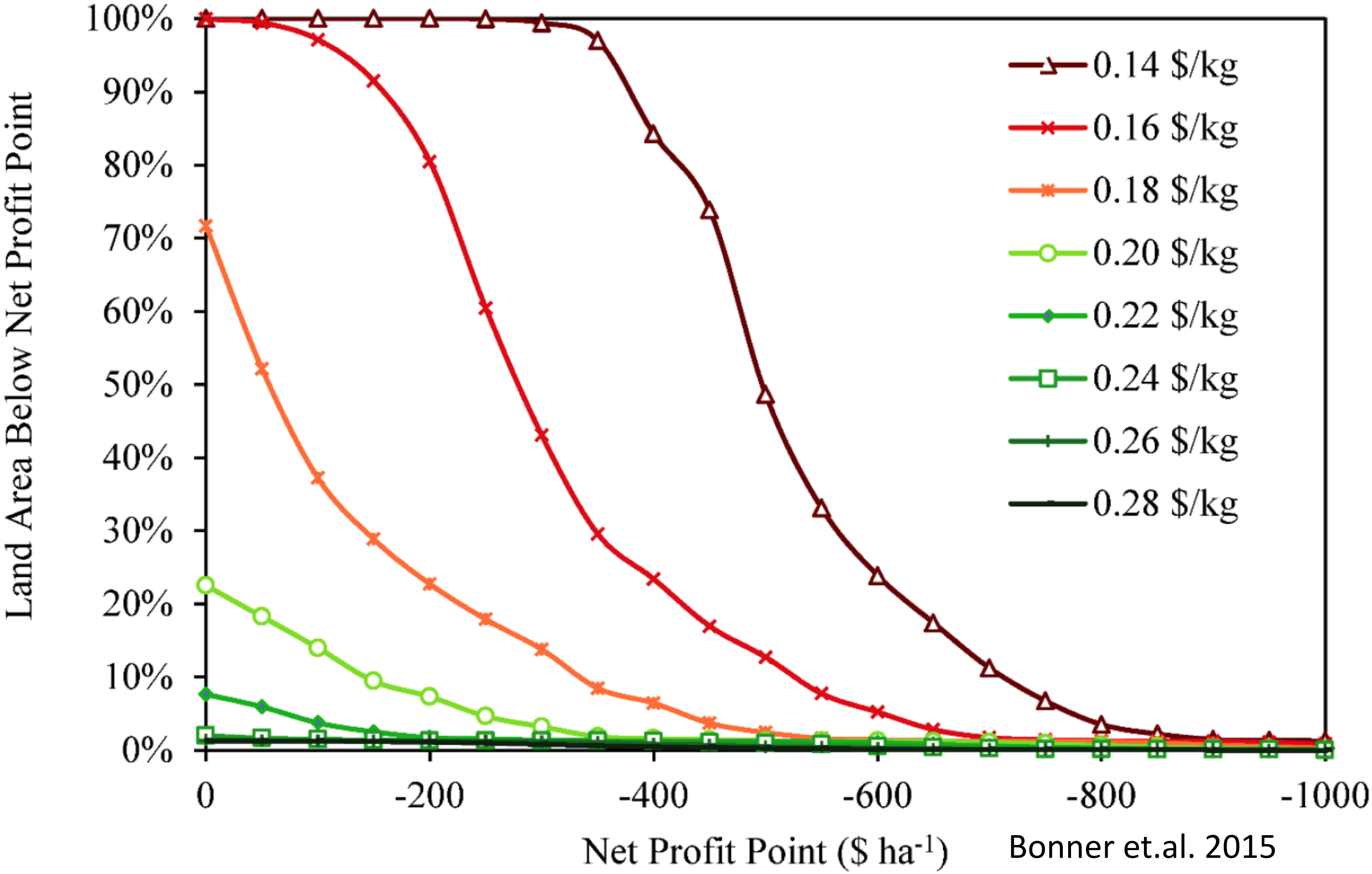


Figure 4. Area within Hardin County, Iowa operating at or below a range of six year average net losses based on varied corn grain price.



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%	-

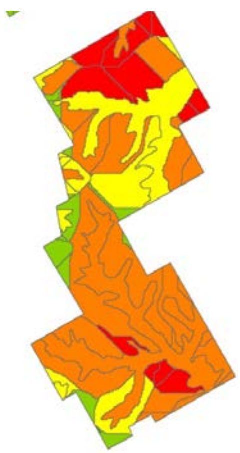
[a] Biomass increase relative to sustainable corn stover availability when no landscape integration is considered;
[b] Mean change in area of only the fields affected by landscape integration at each respective decision point;
[c] All profit calculations are relative to the remaining row crop area of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

Bonner et.al. 2015

Landscape Agroecosystem Modeling

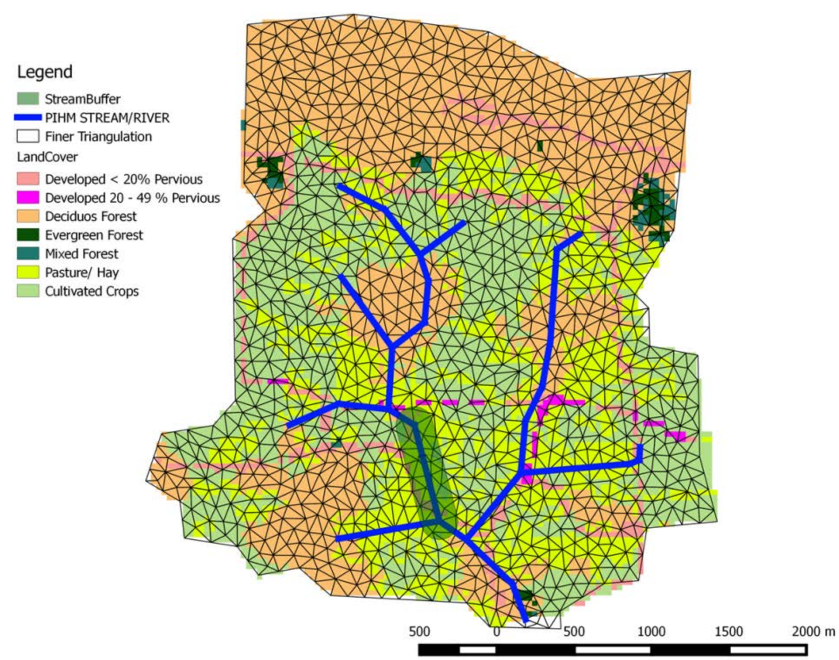
From point models
- CropSyst
- EPIC
- **CYCLES** …

To semi-distributed or semi-coupled models
- APEX
- SWAT



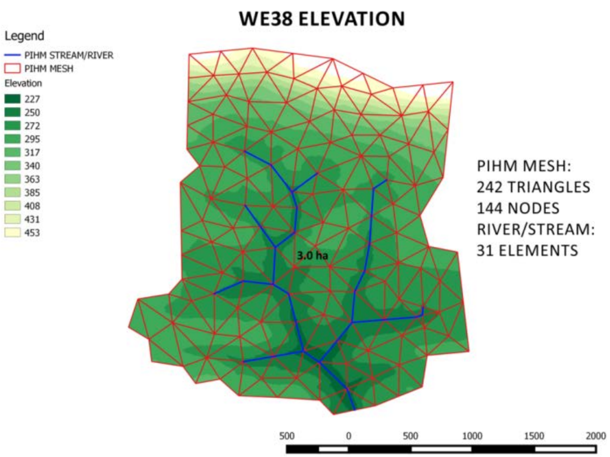
Corn-Corn

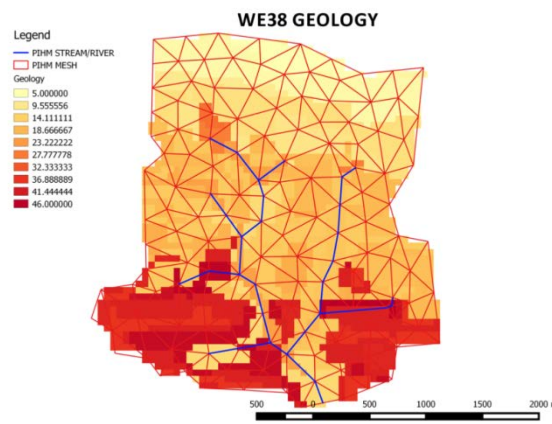
To fully distributed models for landscape design
- **PIHM-CYCLES**

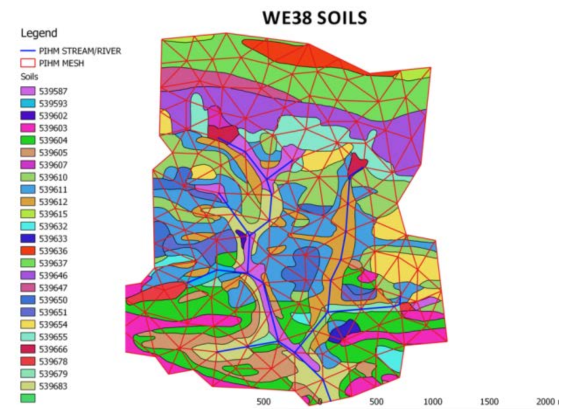


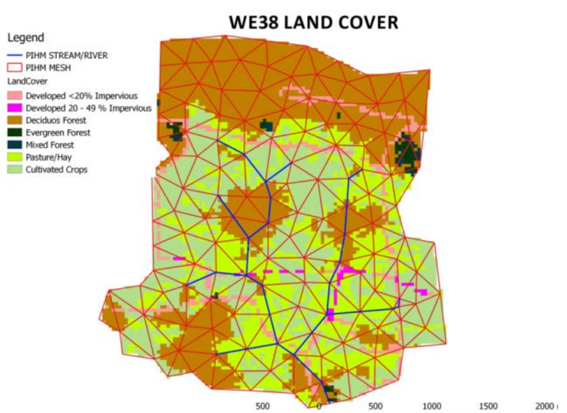
Montes, Kemanian et al. 2015

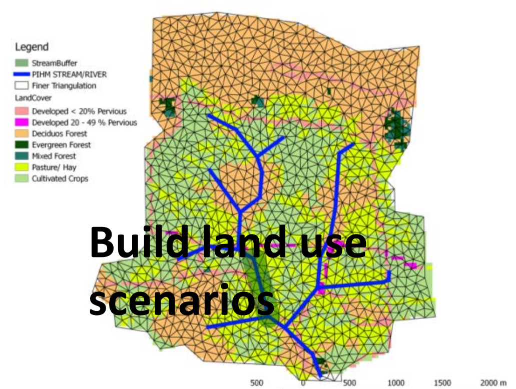
PIHM-CYCLES + Hydroterre System

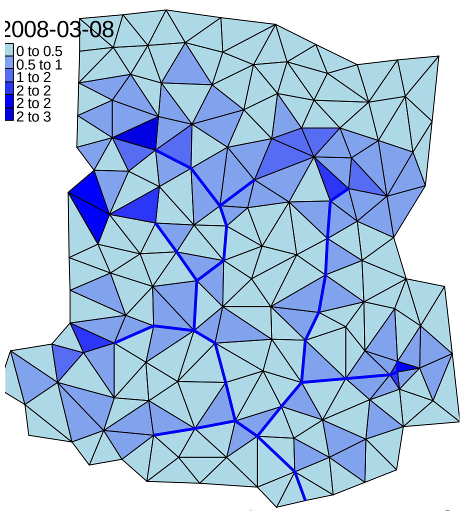








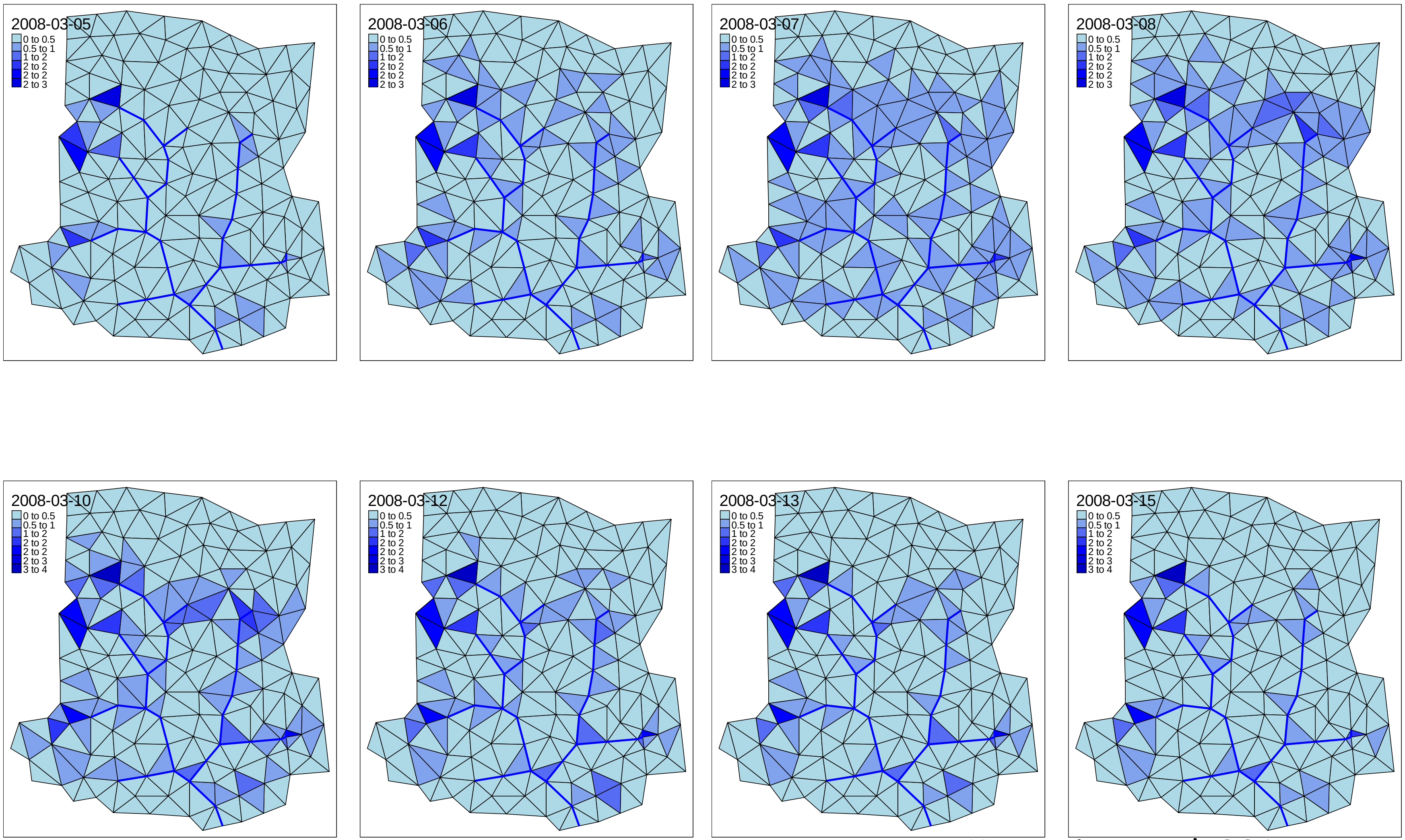




Output – dynamic of ground water storage

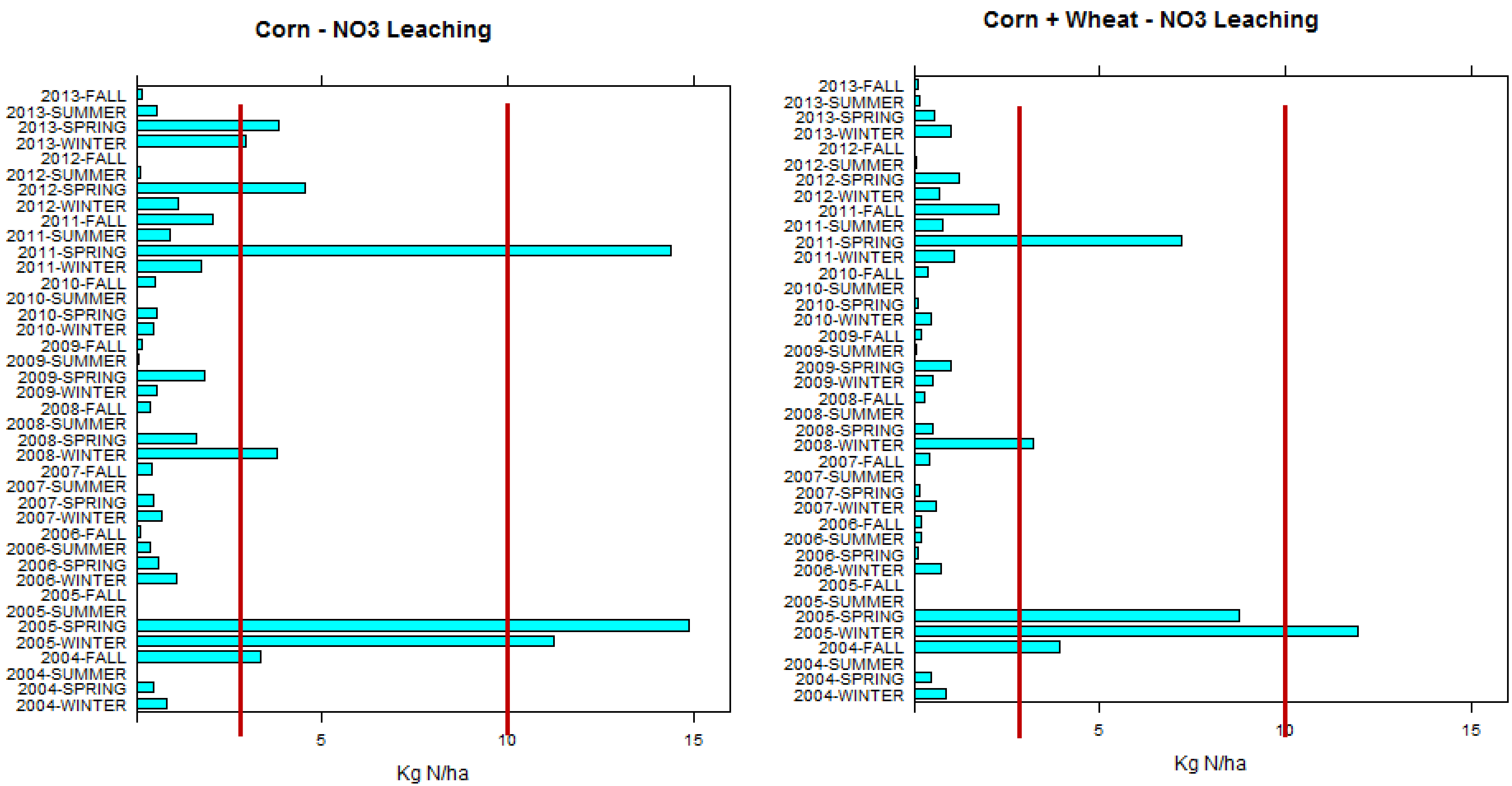
Montes, Kemanian et al. 2015

Example WE38 – 250 ha watershed



Montes, Kemanian et al. 2015

Example WE38 – 250 ha watershed

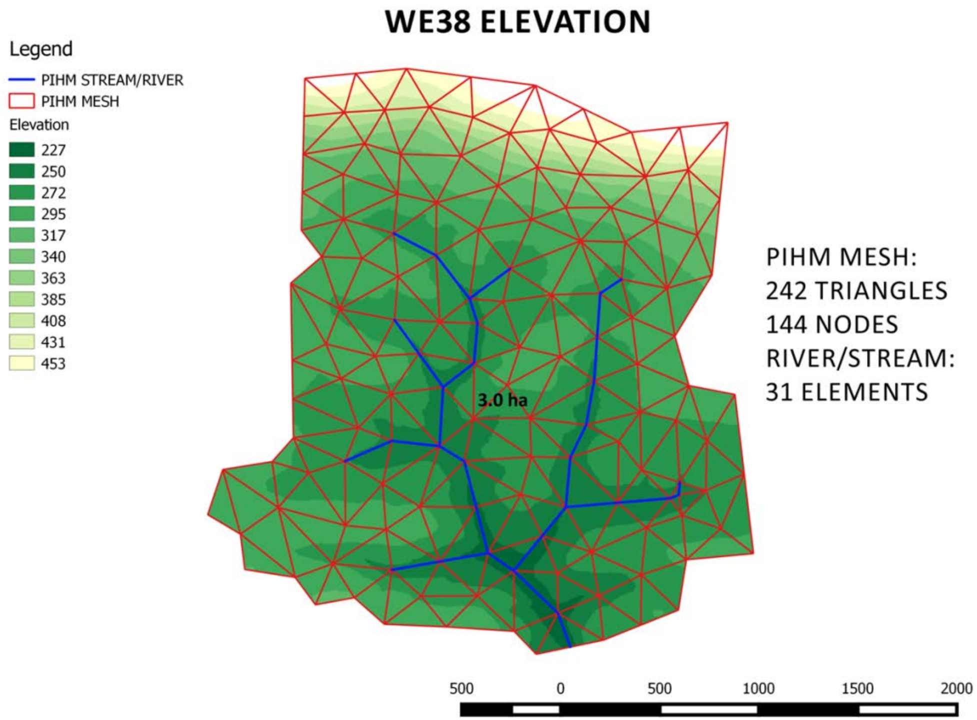


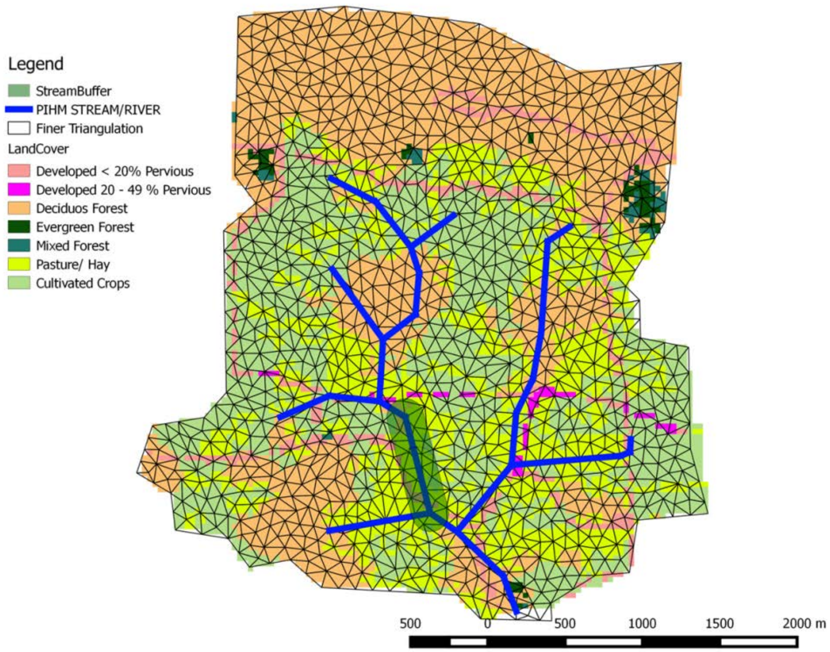
Winter fallow

With winter grass cover crop

Montes, Kemanian et al. 2015

Ongoing: towards finer scales useful for landscape design





242 mesh triangles, 1 ha each

>1,000 mesh triangles
Precision Agriculture
Precision Conservation

Montes, Kemanian et al. 2015

References

- Bonner, I.J., K.G. Cafferty, D.J. Muth, Jr., M.D. Tomer, D.E. James, S.A. Porter, and D.L. Karlen. 2014. Opportunities for Energy Crop Production Based on Subfield Scale Distribution of Profitability. *Energies*, *7*:6509-6526; doi:10.3390/en7106509

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