FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

Alternative Jet Fuel Supply Chain Analysis

ASCENT 1

Project managers: Jim Hileman, Dan Williams, Nate Brown (FAA)
Lead investigator: Kate Zipp, Penn State
Co-Investigators: Tom Richard, Caroline Clifford, and Lara Fowler

April 26-27, 2016
Alexandria, Virginia

ASCENT
AVIATION SUSTAINABILITY CENTER

Motivation

- At current market conditions, it is difficult for biofuels to compete with petroleum-derived jet fuel. Biomass feedstock costs and availability are a major constraint.
- However, certain biomass crops (perennial grasses and winter crops) can provide vital ecosystem services
  - Reduced nutrient runoff and soil erosion
  - Increased soil organic carbon and biodiversity
  - Reduced GHG emission
- Can payments for these ecosystem services (PES) make alternative jet fuels cost effective and help generate the necessary biomass supply & market demand?

Motivation

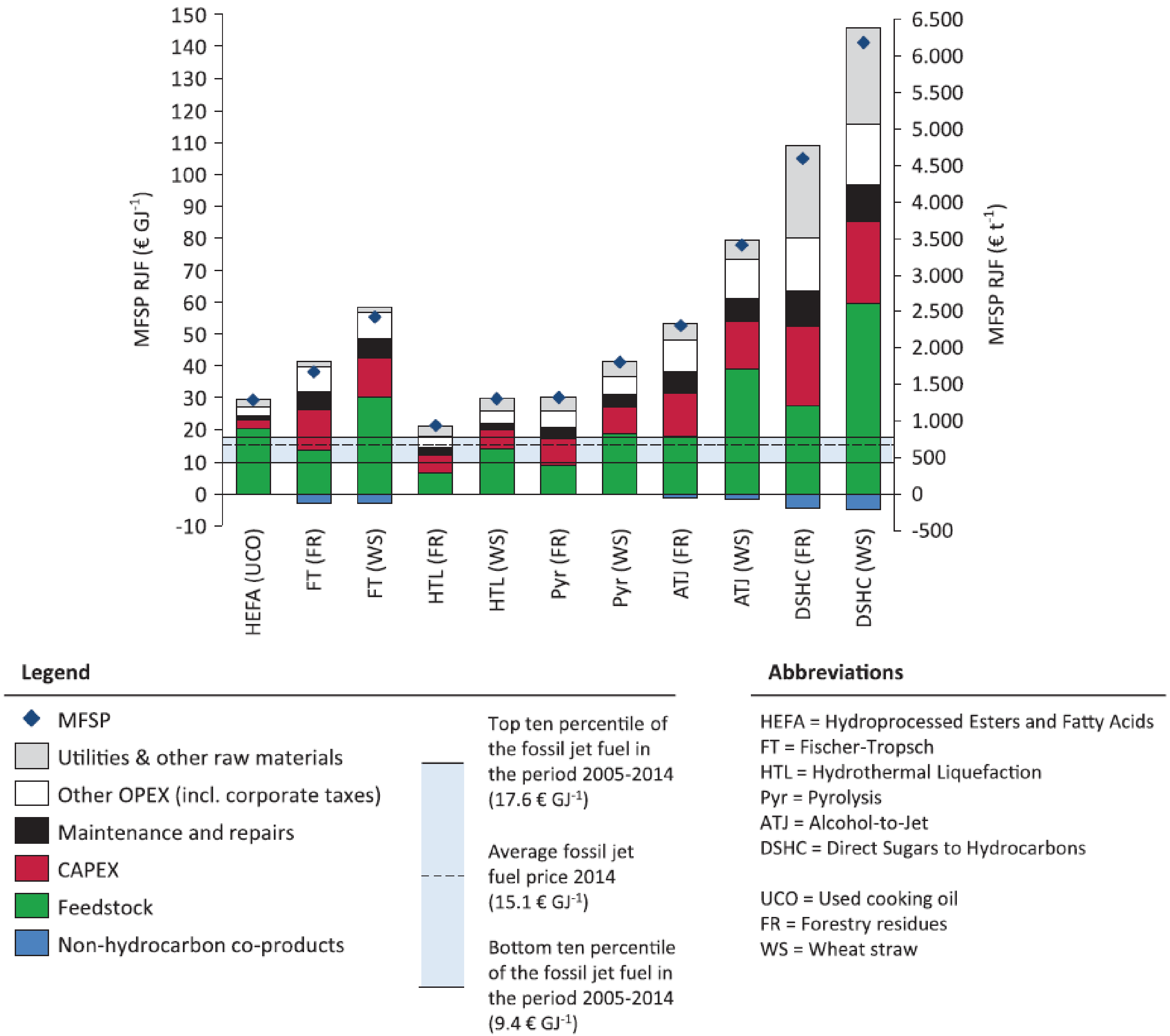

Figure 4. The cost breakdown of the MFSP for greenfield (n^{th} plant) production.

de Jong et al. (2015)

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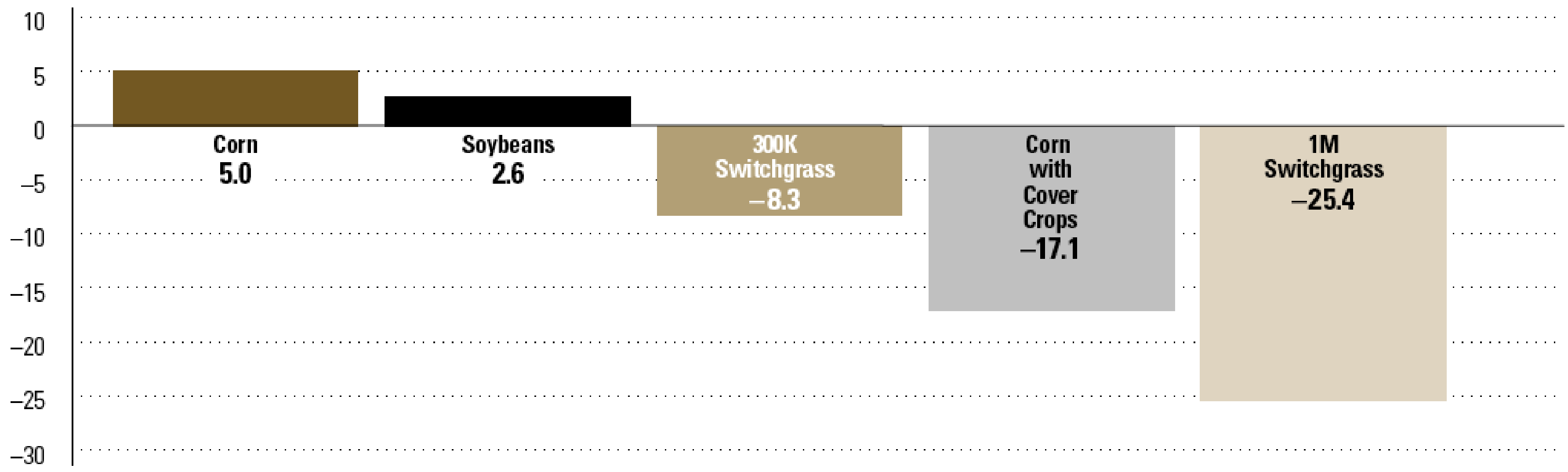
Motivation

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

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Objectives

- Long-term
  - Use potential policies and payments for ecosystem services (PES) to leverage the water quality benefits of certain biomass crops to help support the costs of converting those crops into alternative jet fuels.
- Near term
  - Quantify the water quality benefits associated with the conversion of perennial grasses and winter energy crops to biofuel

Outcomes and Practical Applications

- Outcomes
  - Estimates for ecosystem service values associated with water quality (N, P, sediment), soil quality (carbon) and biodiversity
  - Review of strategies and policies used to monetize these benefits via Payments for Ecosystem Services.
  - Quantified water quality benefits for three biomass feedstock scenarios: winter grasses, winter oilseeds, and perennial energy crops.
- Practical applications
  - Collaborating with UVA, UMES, ORNL, Cornell, SUNY-ESF, Chesapeake Bay Program and state agencies in PA, VA, and MD to engage a broad stakeholder community.
  - This analysis will provide the foundation for market-based strategies to reduce both high biomass feedstock costs and water quality challenges for the Chesapeake Bay Region.

Approach

Market for Biomass Crops

	Supply	Demand
Market goods • Jet fuel	• Potential bioenergy supply • Farmers' conversion decisions	• Aviation industry's willingness to pay (WTP) for jet fuel • Price of fossil jet fuel

Non-market goods
• Water quality
  • Nitrogen reduction
  • Phosphorous reduction
• Soil quality
  • Soil organic carbon
• Biodiversity
• GHG reductions
	• Potential bioenergy supply
	• Farmers' conversion decisions
	• Quantified ecosystem service benefits
		• Willingness to pay (WTP) for ecosystem services benefits

Estimates of Biomass Potential

FIGURE 5

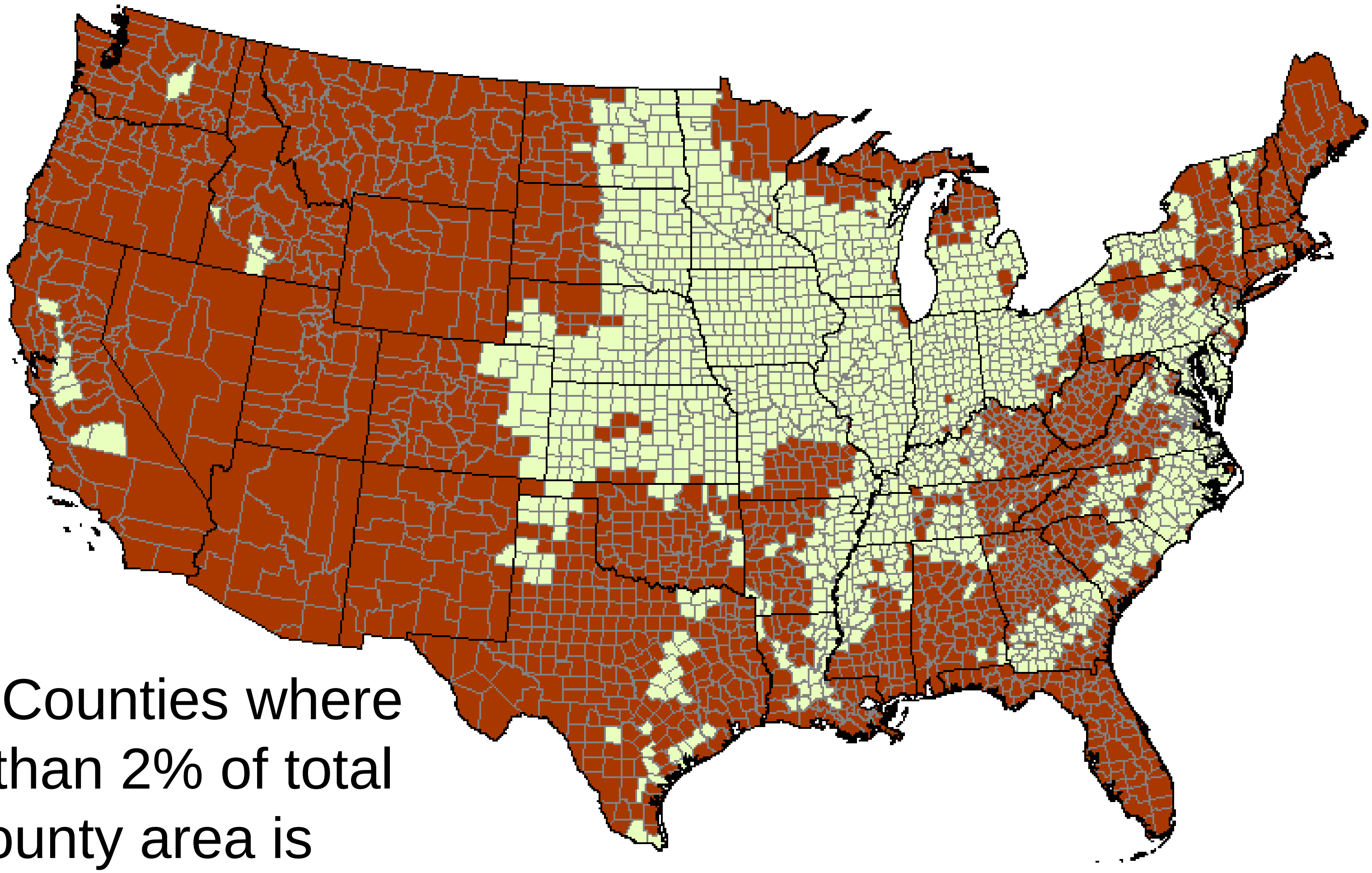
Potential Biomass and Biofuel Production in the Chesapeake Bay Watershed

			Biomass in Metric Tons		Biofuel in Gallons	
Biofuel Crop	**Land Type**	**Acres Available**	**Low Estimate**	**High Estimate**	**Low Estimate**	**High Estimate**
Rye	Corn Grain Cropland	579,225	316,596	474,894	25,327,680	37,991,520
Rye	Soybean Cropland	186,854	115,165	172,748	9,213,200	13,819,840
Barley Grain	Corn & Soy Cropland	1,358,464	868,033	1,302,050	69,442,640	104,164,000
Barley Straw	Corn & Soy Cropland	1,358,464	1,302,053	1,953,080	78,123,180	117,184,800
Switchgrass	Failed Cropland	72,896	55,000	172,500	4,400,000	13,800,000
Switchgrass	Idle/CRP Cropland	447,261	336,000	1,050,000	26,880,000	84,000,000
Switchgrass	Summer Fallow Cropland	39,537	29,000	92,000	2,320,000	7,360,000
Switchgrass	Abandoned Mineland	114,657	13,900	46,400	1,112,000	3,712,000
Switchgrass	Recently Abandoned Cropland	1,680,317	423,000	1,983,000	33,840,000	158,640,000
Slash & Thinnings	All Forests	4.2–11.4m	1,321,800	3,625,400	105,744,000	290,032,000
TOTAL BIOFUEL IN GALLONS:					**356,402,700**	**830,704,160**

SOURCE: Tom L. Richard, Ph.D., Penn State University; Biofuels Advisory Panel's Regional Biofuels Action Team

Chesapeake Bay Commission, 2010

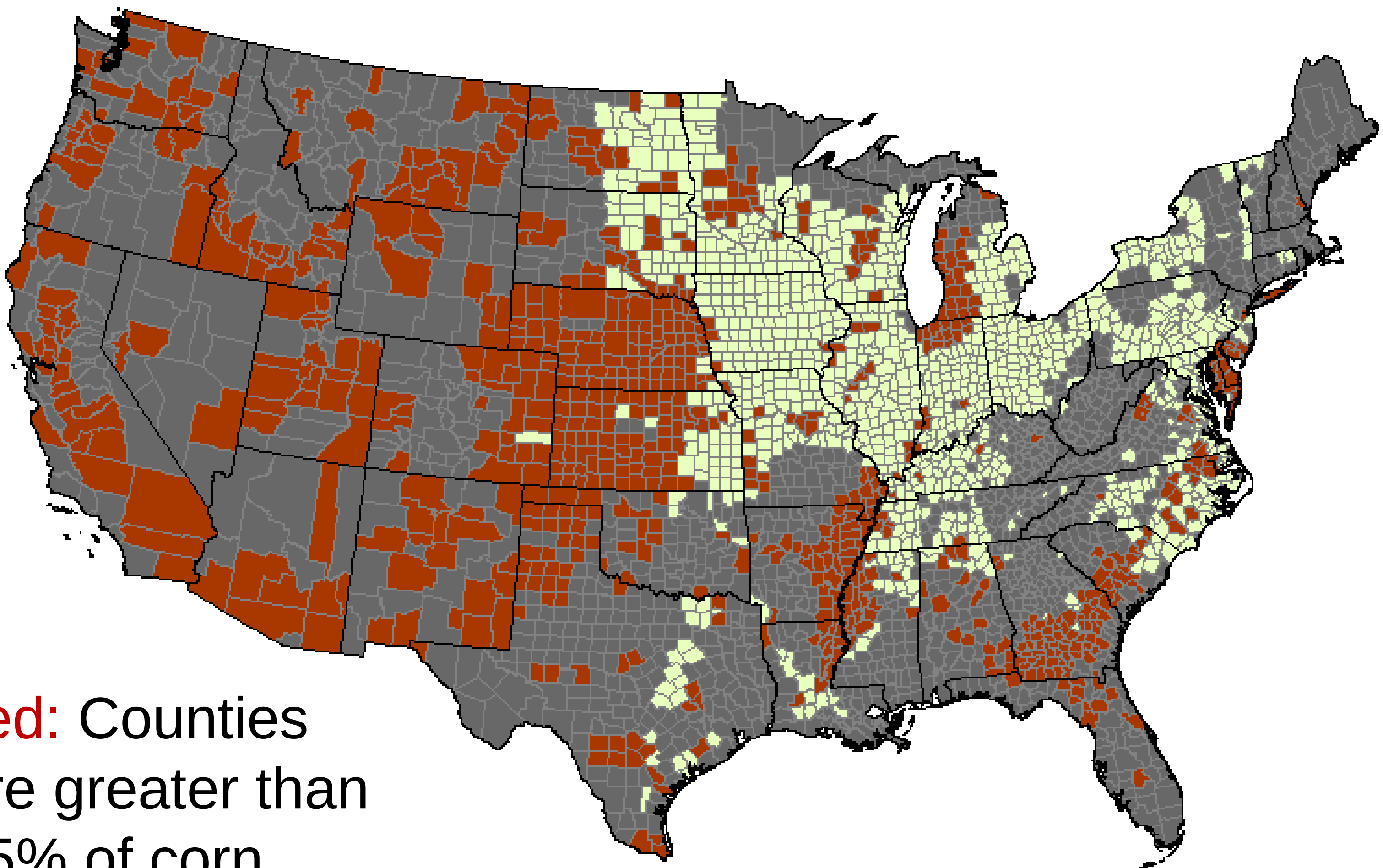
Rule 1: Focus on Corn and Soybeans



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

Feyereisen et al. 2013

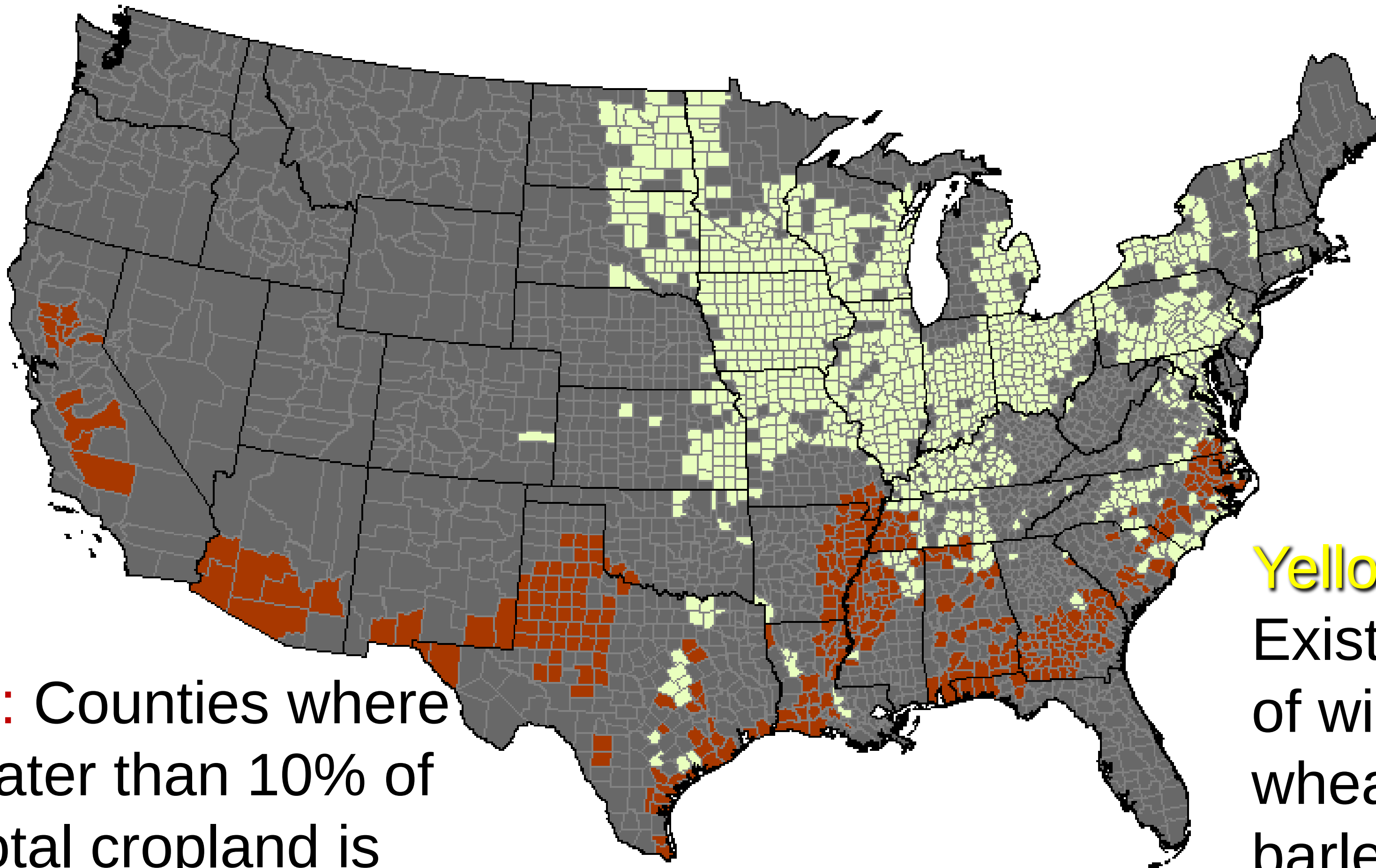
Rule 2: Plant where winter rains are plentiful



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

Feyereisen et al. 2013

Rule 3: Don't compete with other winter crops

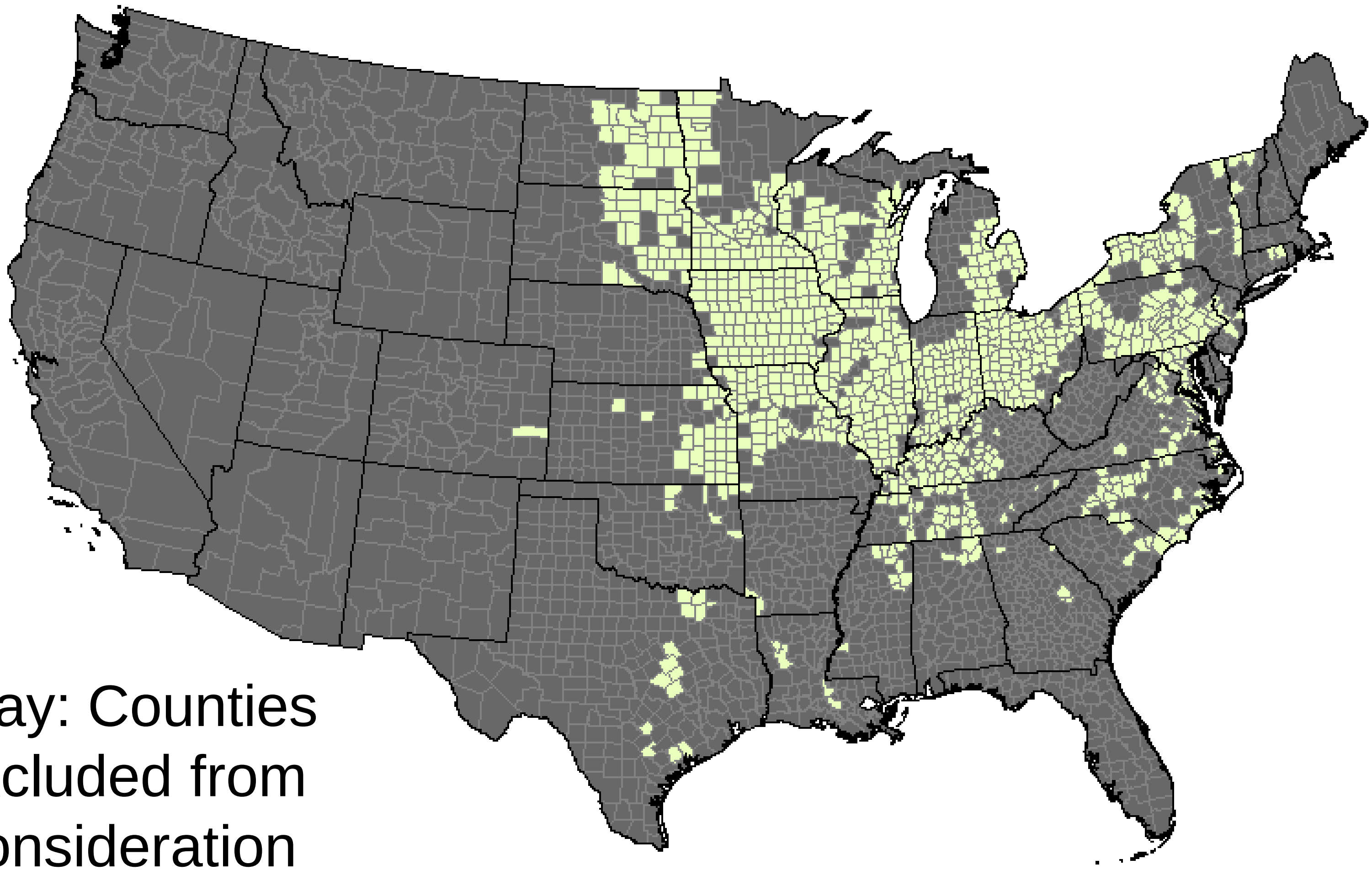


Red: Counties where greater than 10% of total cropland is producing rice or cotton.

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

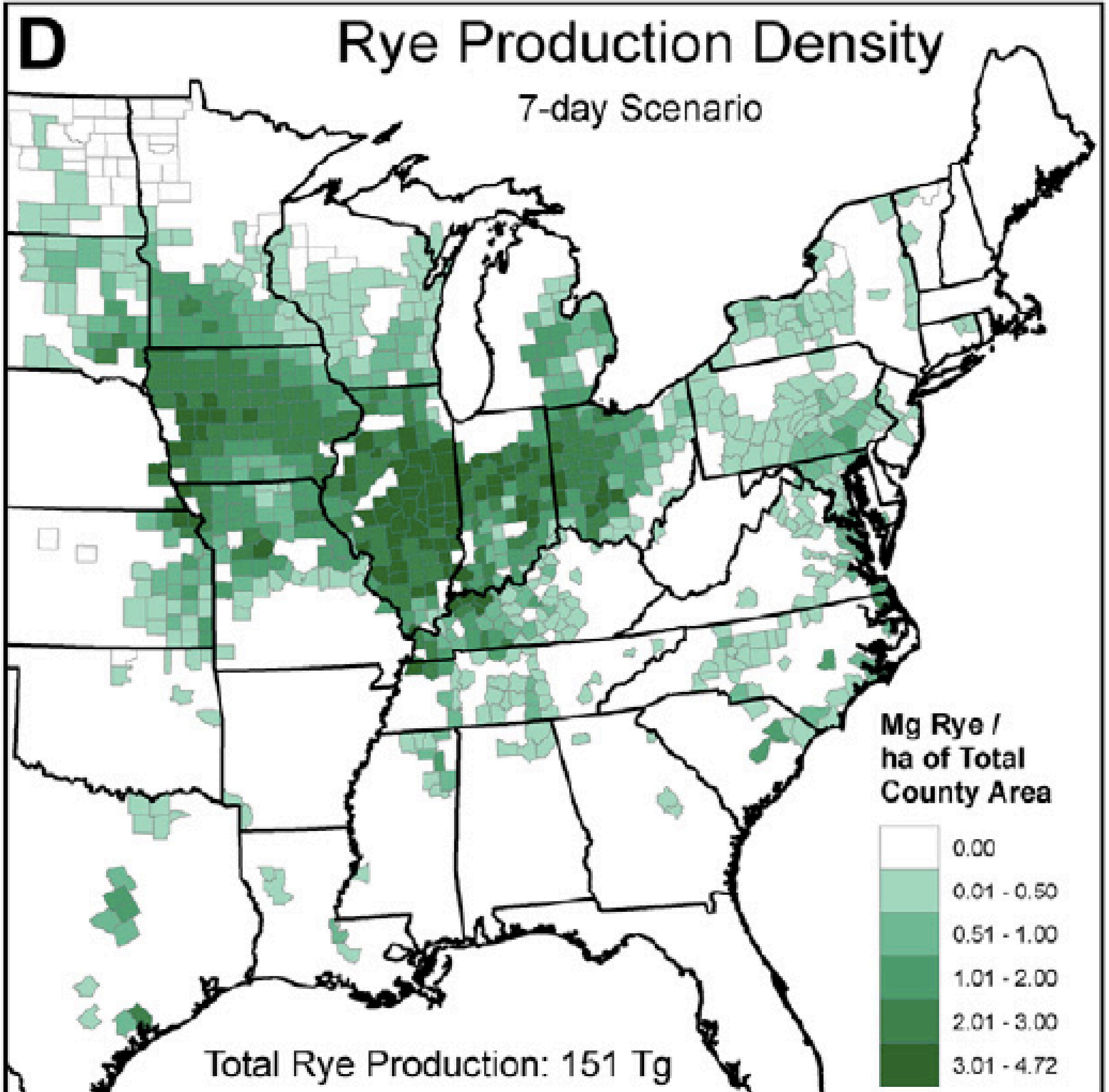
Feyereisen et al. 2013

What's left? Available Winter Cropland...



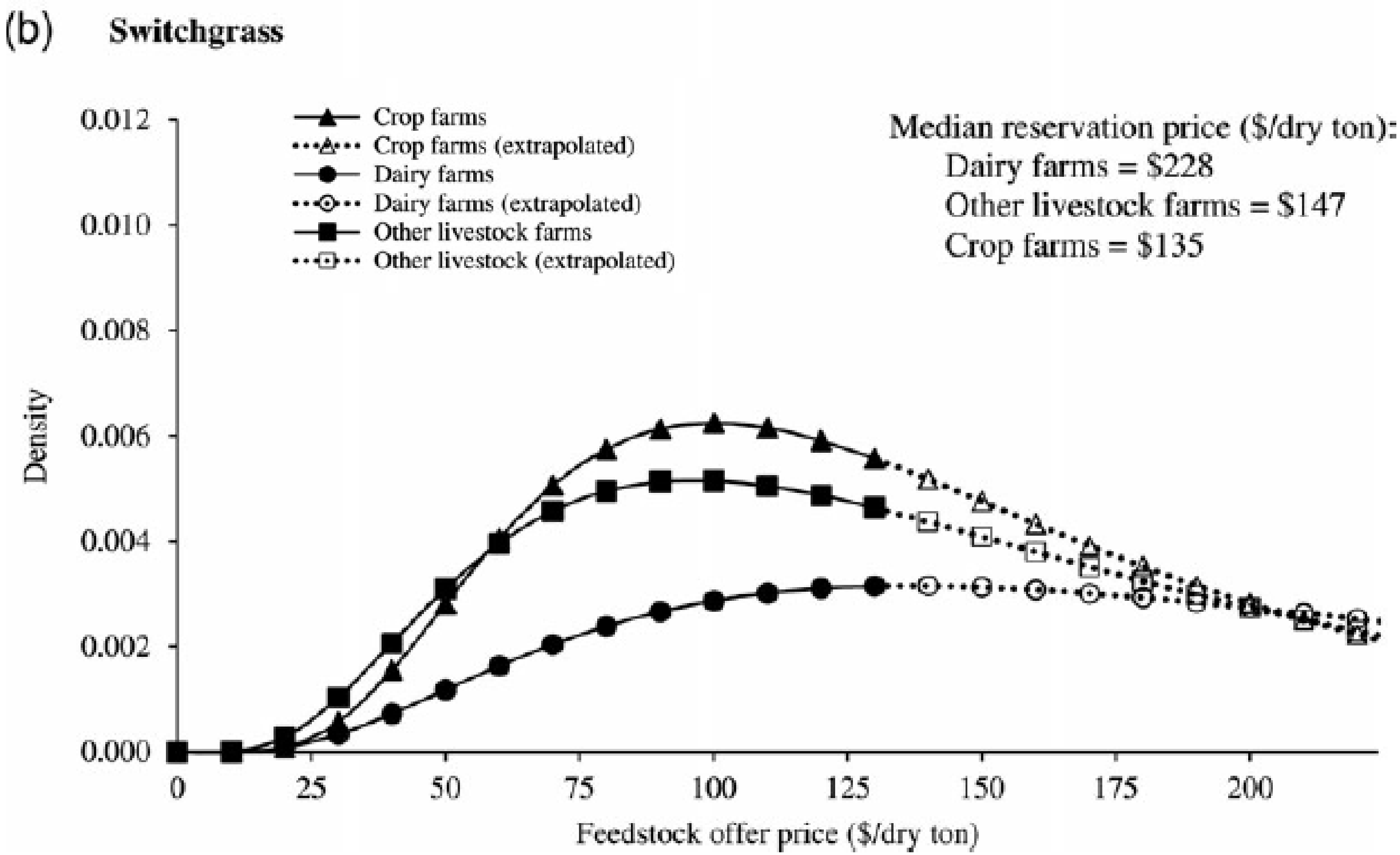
Gray: Counties excluded from consideration for winter rye production

Feyereisen et al. 2013



Feyereisen et al. 2013

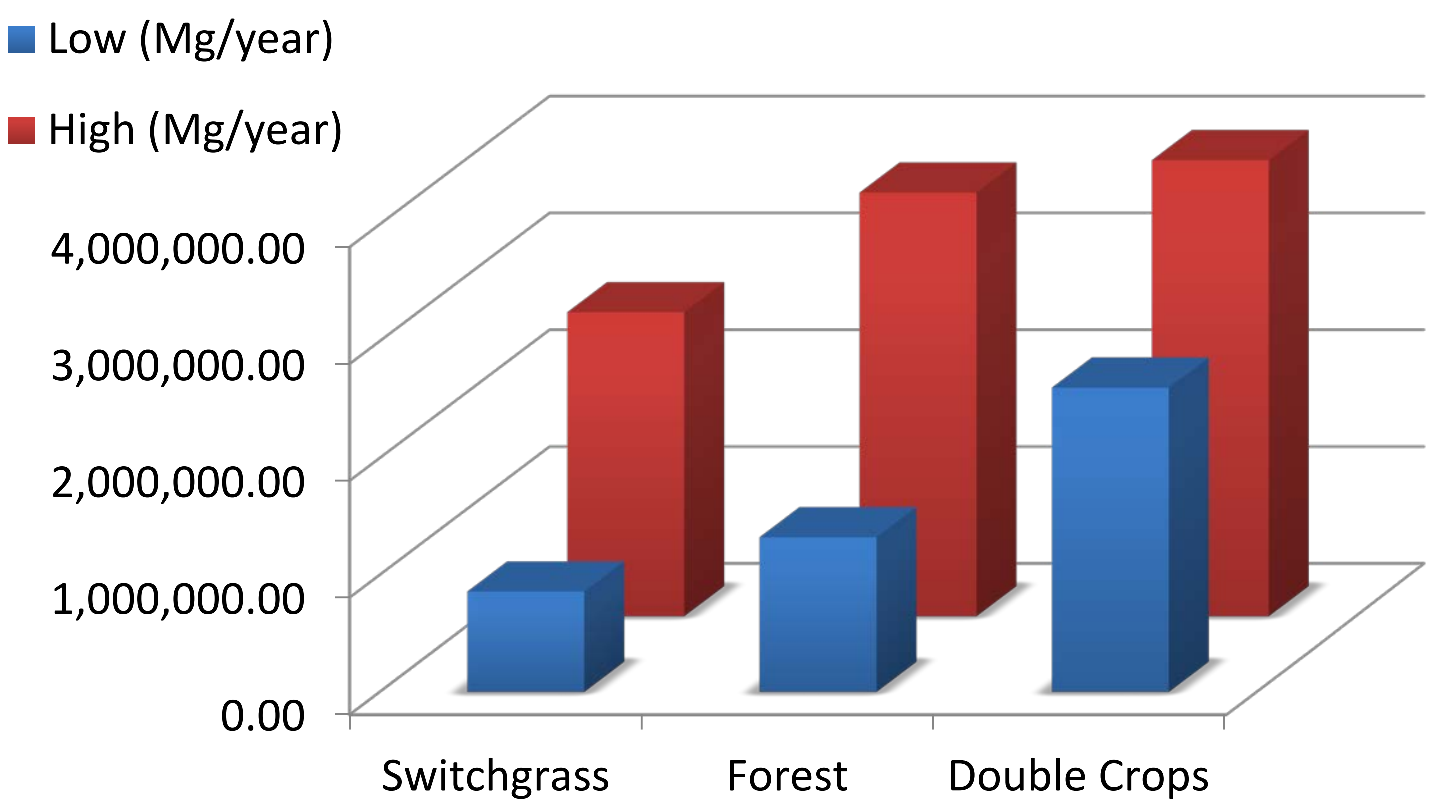
Farmer reservation prices to supply switchgrass



Note: Lines show estimated lognormal probability density functions.

Mooney et al. 2014

Familiarity drives adoption



Chesapeake biomass potential

Chesapeake Bay Commission, 2010

Farmers' supply curves

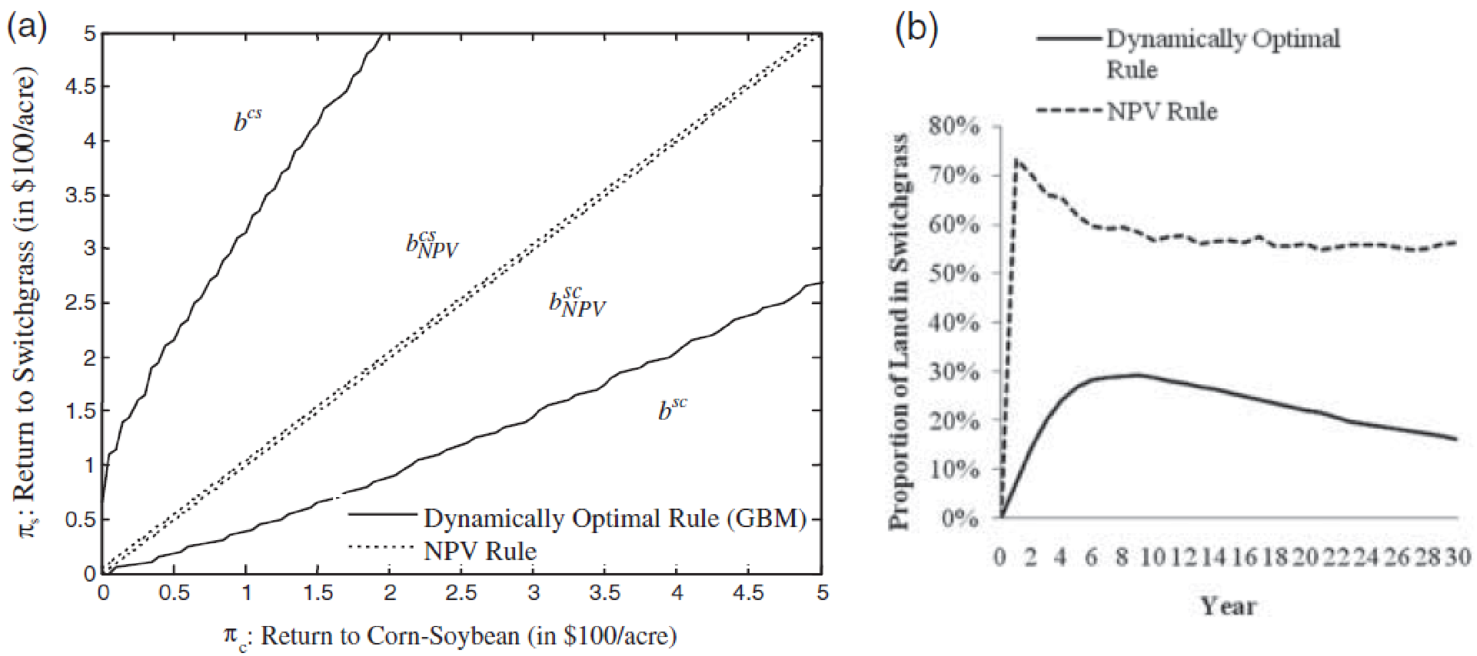


Figure 3. (a) NPV *vs.* dynamically optimal (under GBM): conversion boundaries. (b) NPV *vs.* dynamically optimal rule (under GBM): proportion of land in switchgrass

Song et al. 2011

Recent Accomplishments and Contributions

Market for Biomass Crops

	Supply	Demand
Market goods • Jet fuel	• 150 million dry tons of rye per year (Feyereisen et al. 2013) • 5-12 million tons of biomass per year (Chesapeake Bay Commission 2010) • $100/ton breakeven price (Woodbury et al.) • $135/ton reservation price (Mooney et al. 2014) • $110/ton average annual return from swithgrass → $254/ton conversion boundary (Song et al. 2011) → $6.18/GJ - $15.73/GJ farm-gate prices = $12.36/GJ - $31.46/GJ biofuel prices	• $7.19/GJ - $8.12/GJ
Non-market goods • Water quality • N reduction • P reduction • Soil quality • Biodiversity • GHG reduction	• Maize to switchgrass = 23 kg N ha^{-1} y^{-1} reduction in N loading to the Chesapeake Bay (Woodbury et al.)	• $10.7 kg N^{-1} (Woodbury et al.) • $1.4 GJ^{-1}

Schedule and Status

- We have preliminary estimates of the water quality benefits from perennial grasses and winter crops and estimates of what various state programs are willing to pay for these ecosystem services.
  - We are working with PIHMs to more accurately estimate water quality benefits.
- We have preliminary estimates of farmers' supply curves for these biomass crops and aggregate supply.
  - We are surveying farmers in PA, OH, NY to estimate their supply curves.
  - We are updating the conversion boundaries from Song et al. 2011 to be consistent with ASCENT assumptions.
- We are in the process of estimating the effects of various PES on farmers' supply curves and thus aggregate supply and aggregate water quality measures.

Interfaces and Communications

- External
  - Publications listed at the end, more in process
  - Linked to the USDA-NIFA NEWBio Sustainable Bioenergy Coordinated Agricultural Project and FAA-USDA-DOE's Farm 2 Fly 2 regional effort with the University of Virginia and the University of Maryland Eastern Shore.
- Within ASCENT
  - "Aviation Biofuels and the Chesapeake Watershed: Coupling Sustainable Energy with Sustainable Agriculture" Tom Richard et al. to CAAFI on February 26, 2016

Summary

- Summary statement
  - There is a gap between the prices of biofuels that would induce farmers' to grow bioenergy crops and prices that would induce the aviation industry to buy biofuels. Payments for some of the other ecosystem services that bioenergy crops provide (e.g. water quality benefits) present an opportunity to start to close this price gap.
- Next steps?
  - Gather more information on the range of PES
  - Estimate the effects of PES on farmers' supply curves.
- Key challenges/barriers
  - Estimating hypothetical biomass supply curves.
  - Scale and spatial heterogeneity

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Contributors

- Kay DiMarco, Amanda Ramcharan, Felipe Montes and Armen Kemanian, Penn State; Matt Langhotz, DOE Oak Ridge National Lab; Peter Woodbury, Cornell University; Gary Feyereisen, USDA-ARS; Gustavo Camargo, Monsanto; Xiongjun Shao and Lee Lynd, Dartmouth College