Multifunctional Management of Grassland Agriculture

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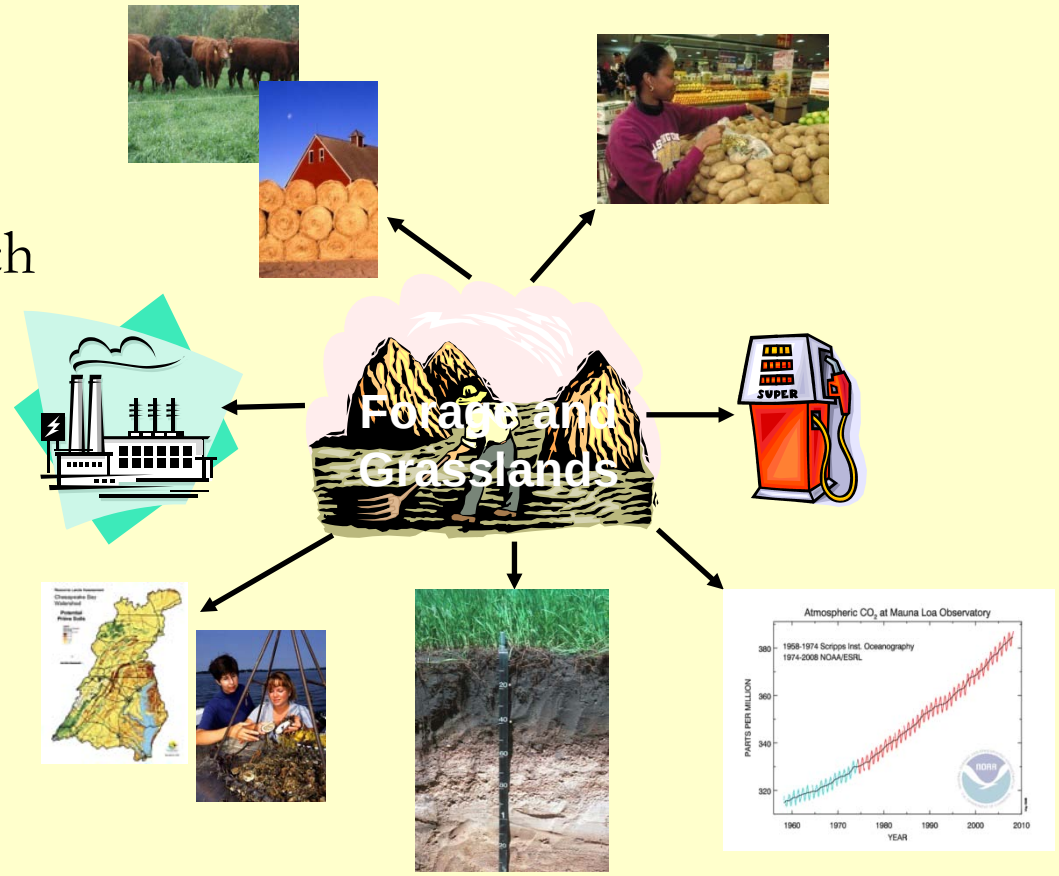


Agriculture, ecosystem services, and multifunctionality

US agriculture/energy programs

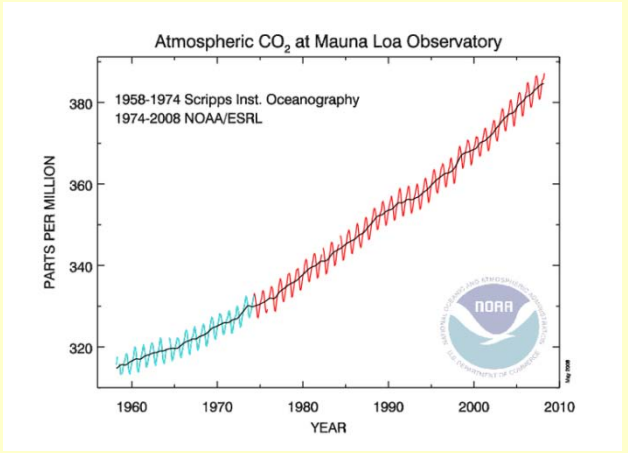
- Food, Conservation, and Energy Act of 2008 (Farm Bill)
- NRCS
  - Conservation Effects Assessment Project (CEAP)
  - Conservation Stewardship Program (CStP)
  - Environmental Quality Incentives Program (EQIP)
- National organic standards
- Energy Independence and Security Act of 2007
- **But, farmers are still interested in production and profit**

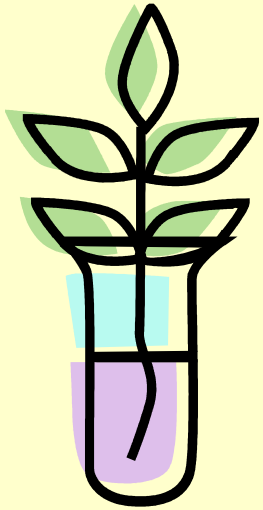
Traditional ecosystem services from grassland agriculture

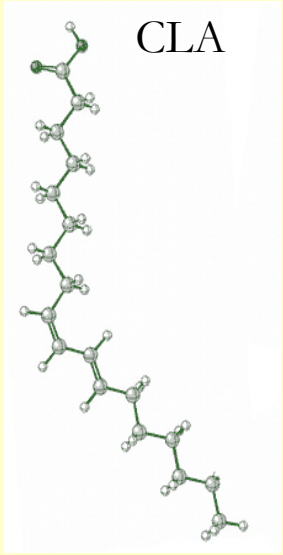
- Food, feed, fiber
  - Hay is $11B crop in US
  - Forages contribute ~$30-40B to the ruminant livestock industry
- Soil and water conservation
  - Erosion control
  - Water quality protection

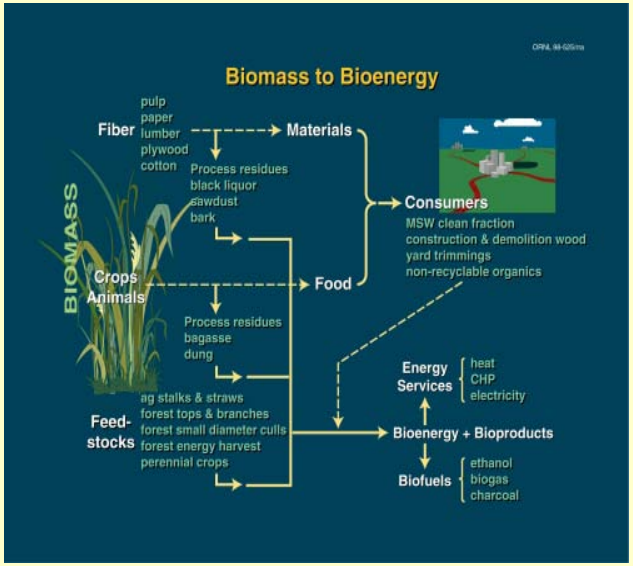
New or emerging ecosystem services from grassland agriculture

- Biodiversity conservation
- Greenhouse gas mitigation
- Bioenergy
- Carbon sequestration
- Green space
- Functional foods
- Bioproducts



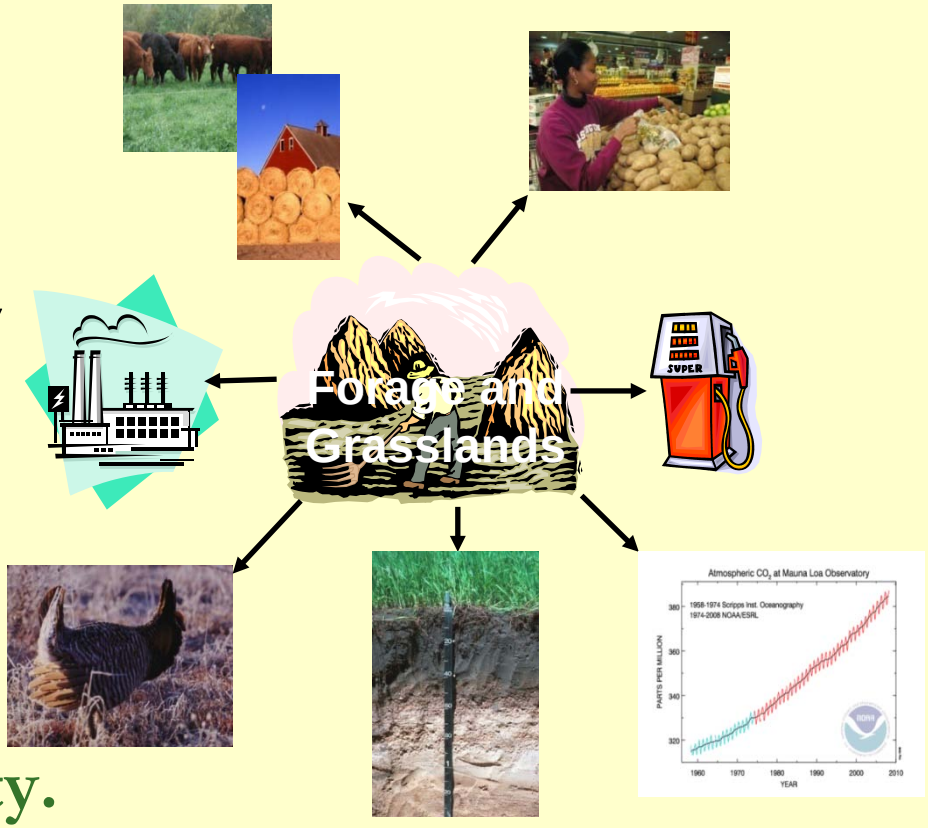






Complex ecosystems provide multiple benefits, require multiple species.

Duffy. 2008. Front. Ecol. Environ. 7:437

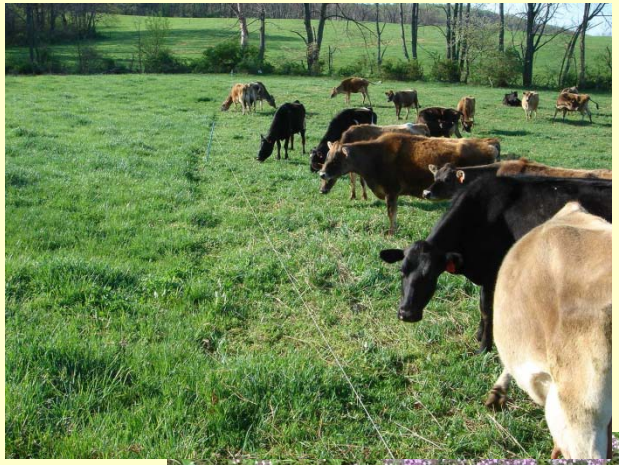


Managing for multiple functions and services requires greater biodiversity.

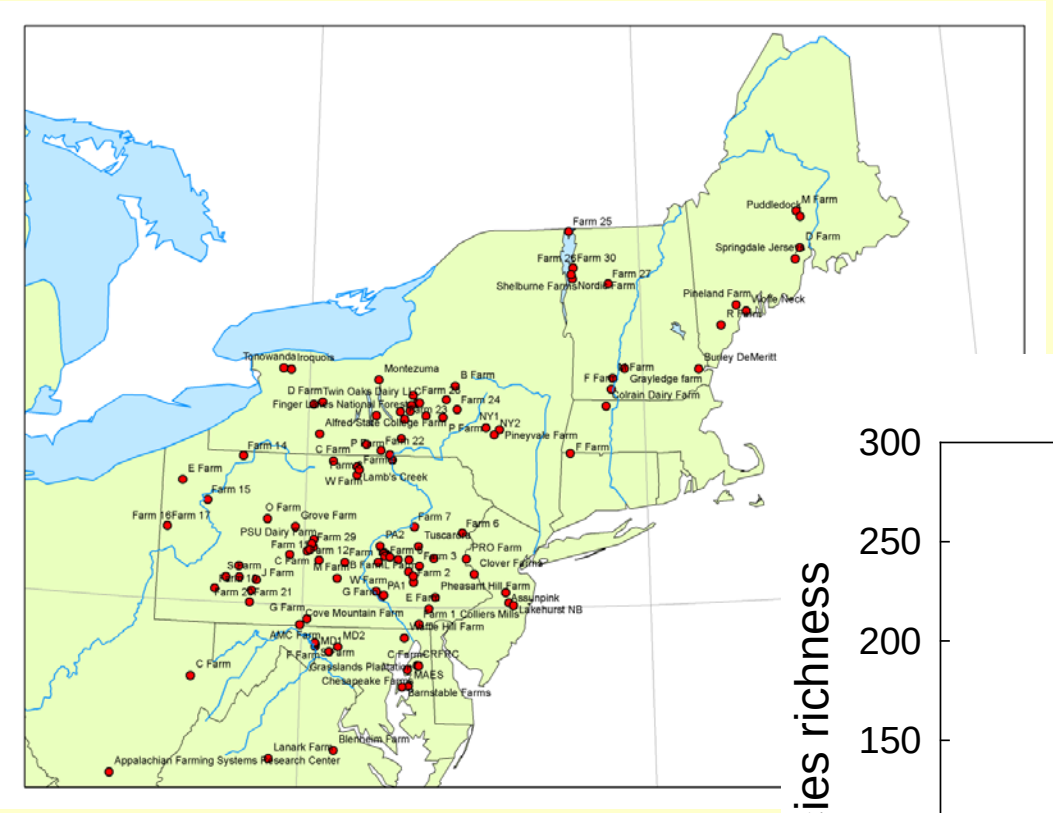
Zavaleta et al. 2010. PNAS 107:1143

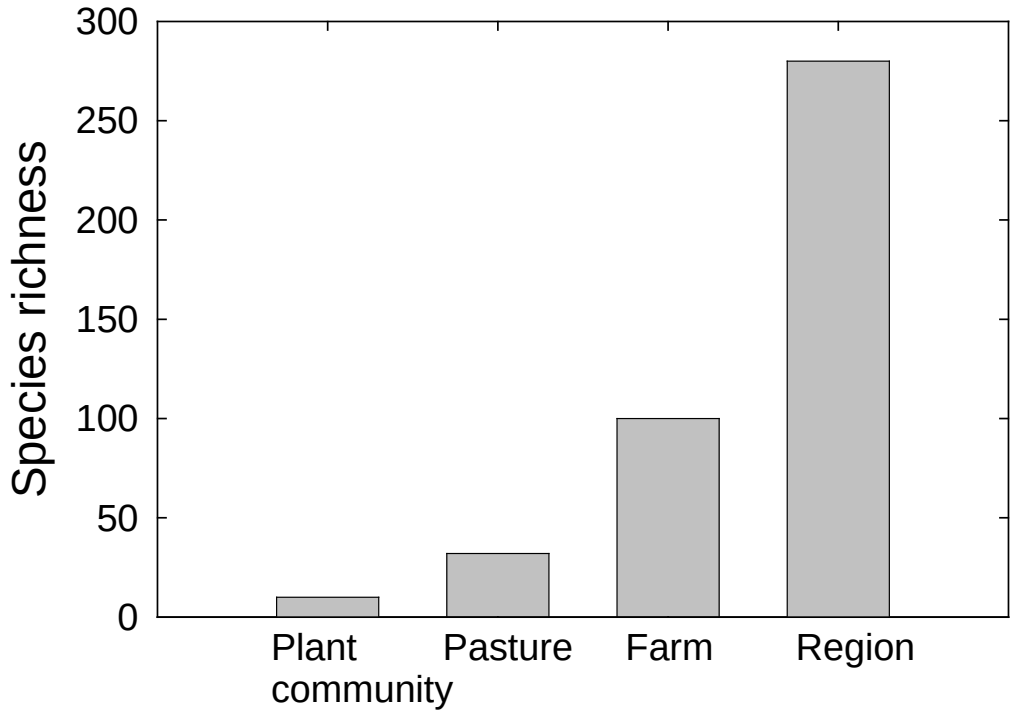
Is managing for plant diversity useful in forage and grazing lands?

- Perspective from research in the Northeast U.S.
  - Plant diversity in northeastern grazing lands
  - Diverse forage mixtures
    - Productivity (plant and animal)
    - Resistance to weed invasion
    - Other



Pasture plant species richness at different scales in the northeastern US



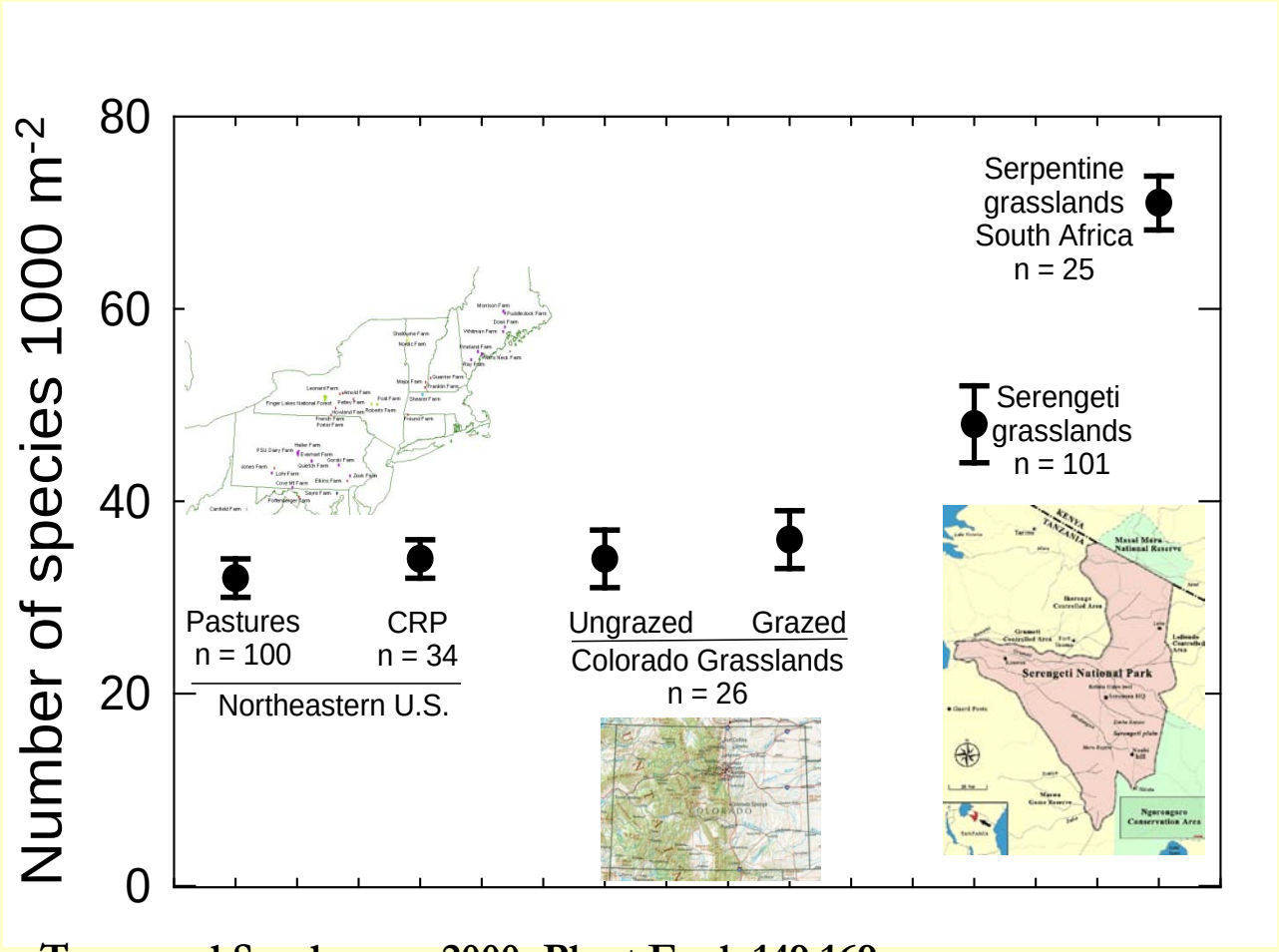


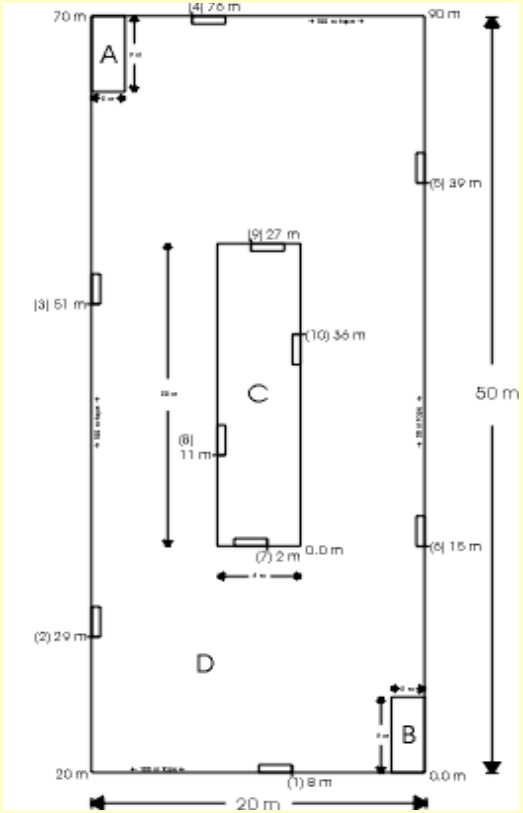
Tracy and Sanderson. 2000. Plant Ecology 149:169.

Adler et al. Ecol. Appl. 19:2202

Goslee and Sanderson. 2010. Landscape Ecology 25:1029.

Plant diversity in different grasslands





Modified Whittaker Plot

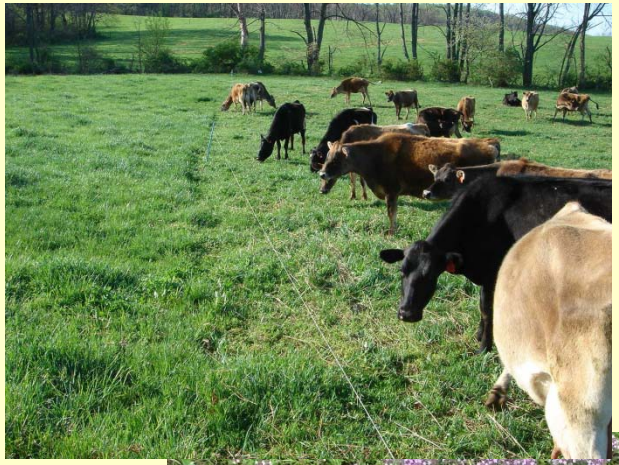
$1\ m^2 – 1000\ m^2$

Tracy and Sanderson. 2000. Plant Ecol. 149:169
Goslee and Sanderson. 2010. Landscape Ecol. 25:1029
Adler et al. 2009. Ecol. Appl. 19:2202
Stohlgren et al. 1999. Ecol. Appl. 9:45
Reddy et al. 2009. Plant Ecol. 201:365
Anderson et al. 2007. J. Biogeography 34:313

Pasture biodiversity–plants, seeds, bugs

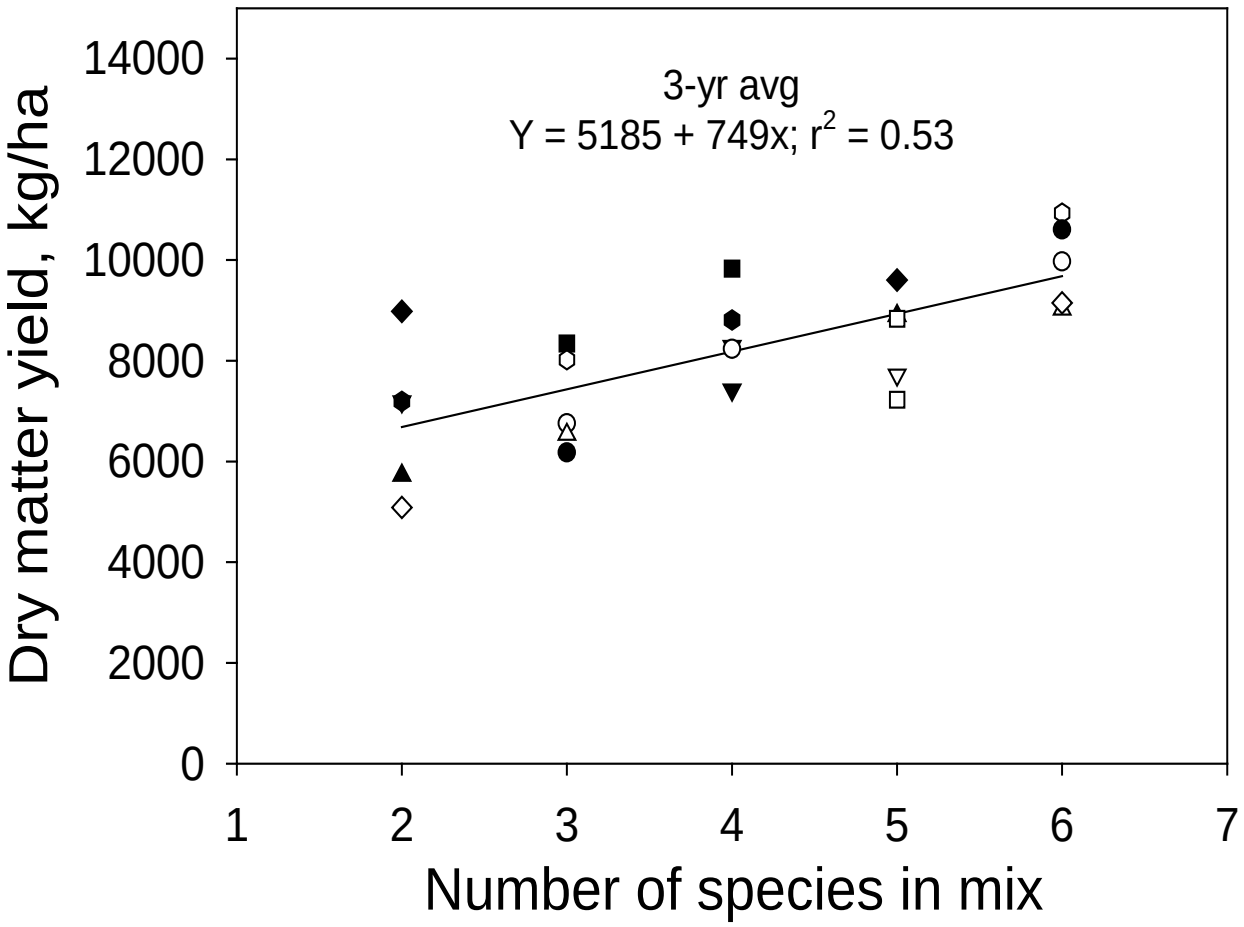
Is managing for plant diversity useful in forage and grazing lands?

- Perspective from our research in the Northeast U.S.
  - Plant diversity in northeastern grazing lands
  - Diverse forage mixtures
    - Productivity (plant and animal)
    - Resistance to weed invasion
    - Other



Commercial mixtures evaluated under grazing in Massachusetts, Pennsylvania, and Vermont

Small-plot research



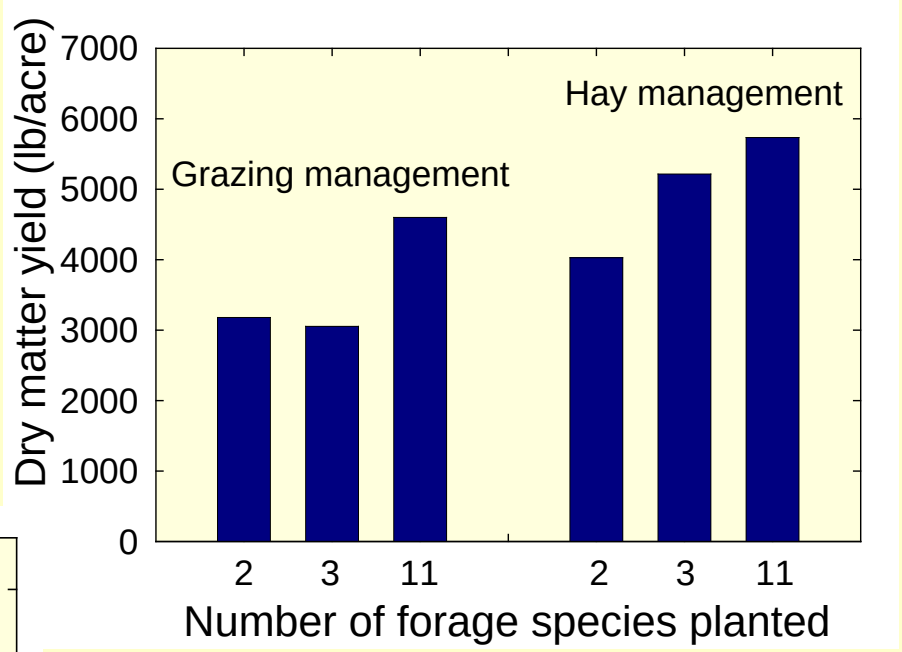
Stephen Herbert, Matt Sanderson, Sid Bosworth. Unpubl. Northeast SARE grant 2007–2010.

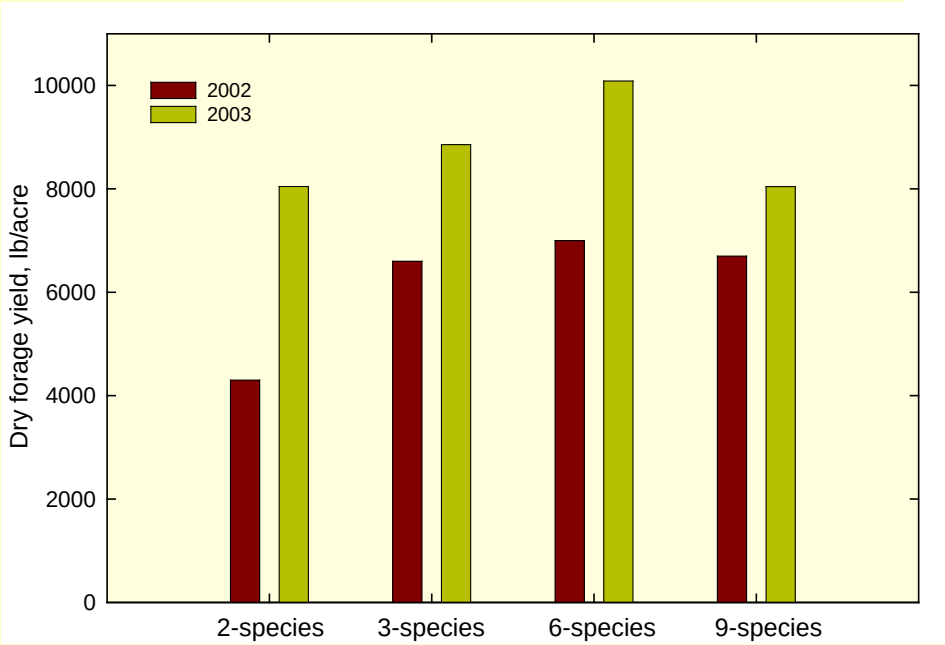
Diversity and Pastures: Productivity

Grazed pastures, eastern PA farm, 4-yr avg.

Positive relationship between mixture complexity and forage yield.

Skinner et al. 2006. Agron. J. 98:320.





Grazed pastures, central PA

Complex mixtures yield more than 2-species mix in 2002 (dry year). No difference in 2003 (wet year).

Sanderson et al. 2005. Agron. J. 97:1465

Diversity and Pastures: Animal Productivity

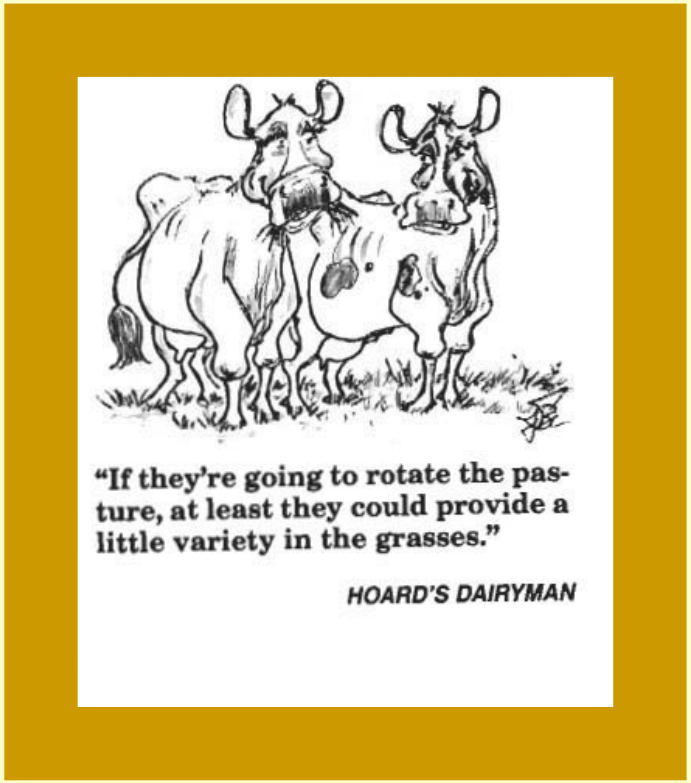
Dairy grazing trial at Pennsylvania
-Individual animal performance same on diverse mixtures
-Production per unit area greater on diverse mixtures
-Beneficial fatty acids (C18-2, cis-9 trans-11) slightly higher

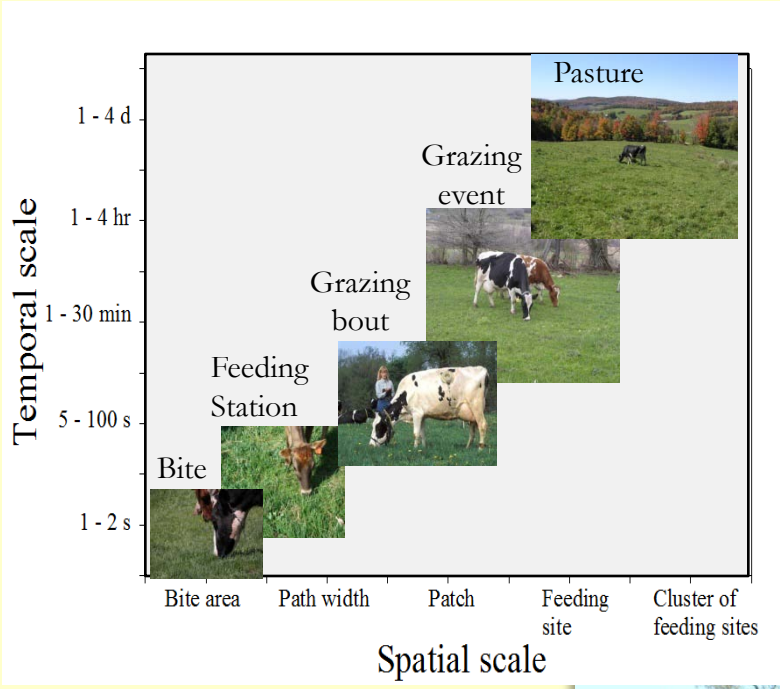
Treatment	Milk production	Herbage intake	Milk production	C18-2	cis-9, trans-11
	----lb/cow/day----		lb/acre	g/100 g FA	g/100 g FA
Grass-clover	75	28	4700	4.06	0.87
3-species	78	27	7070	4.69	1.02
6-species	76	27	7700	4.50	0.99
9-species	76	26	6950	4.94	1.04

Soder et al. 2006. J. Dairy Sci. 89:2158 Soder et al. 2007. Crop Sci. 47:416

"Educated cows eat more than grass"

Kathy Voth Livestock for Landscapes



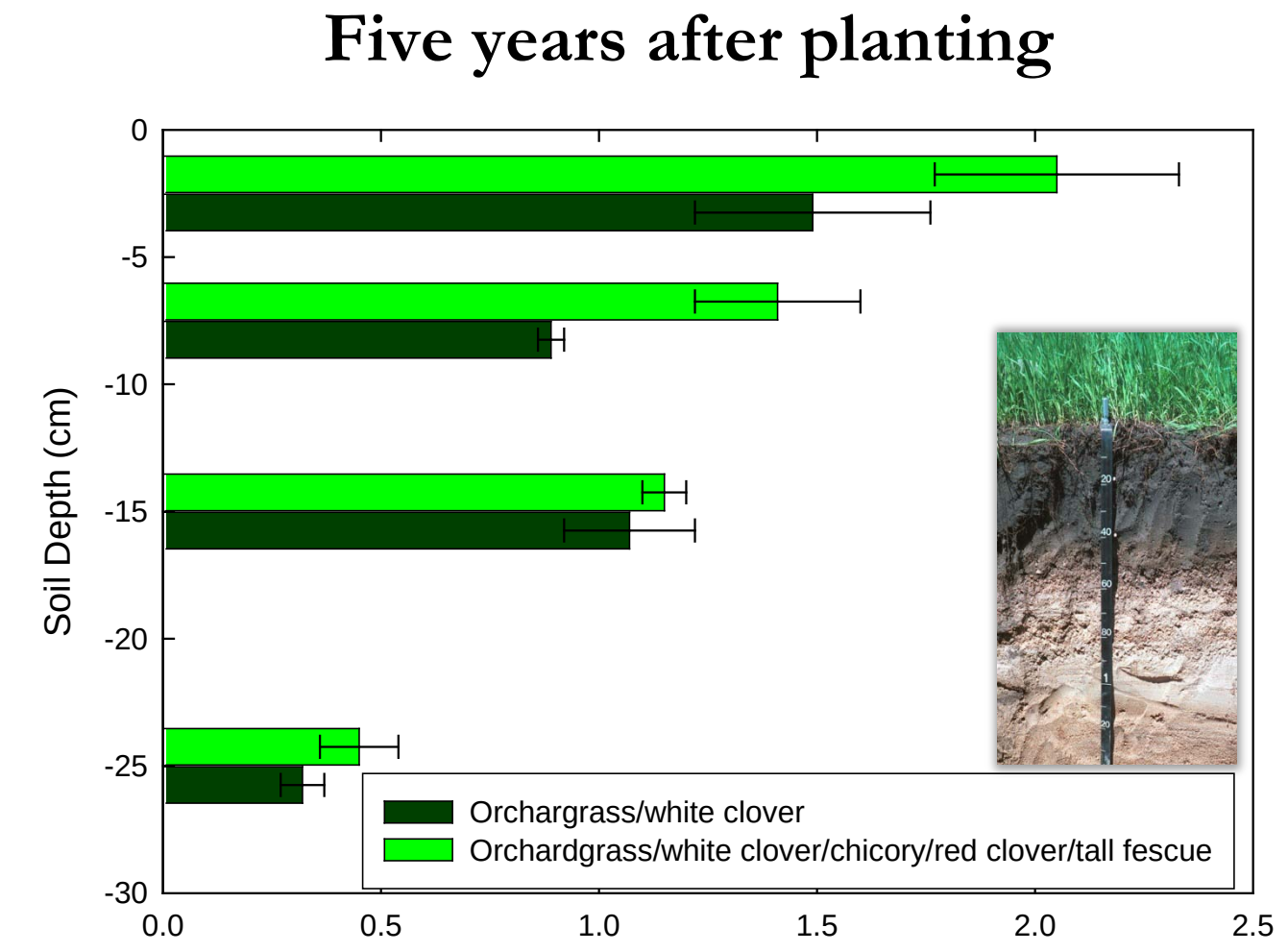


Including deeper-rooted species in mixtures improved drought resistance by better root distribution

Depth	2-species	3-species	11-species
(inches)	-------% of total root biomass--------		
0-2	73	59	48
2-6	15	22	25
6-12	8	11	16
12-24	4	8	12

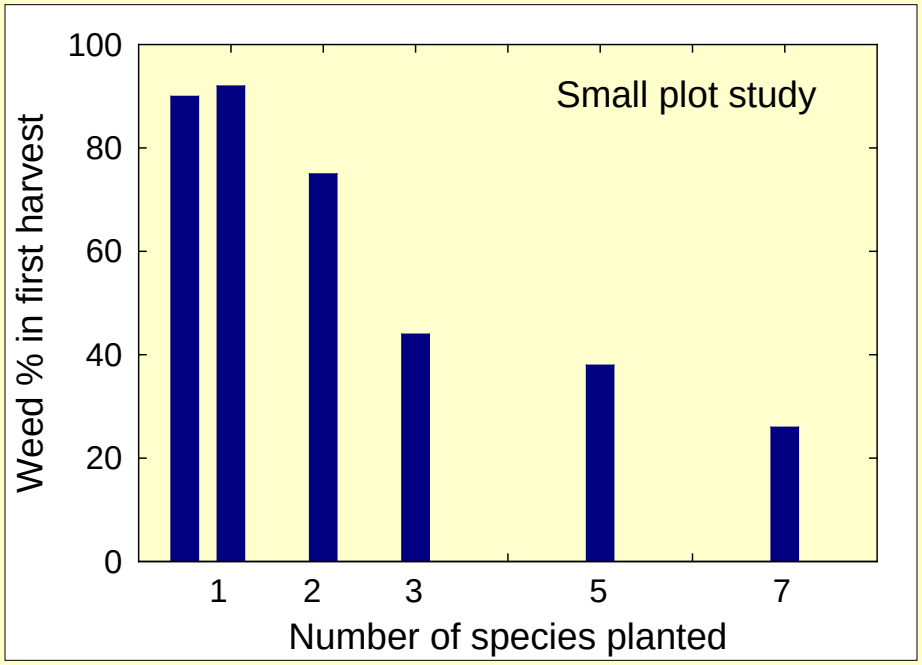
Skinner et al. 2006. Agron. J. 98:320.

Soil carbon levels under mixtures



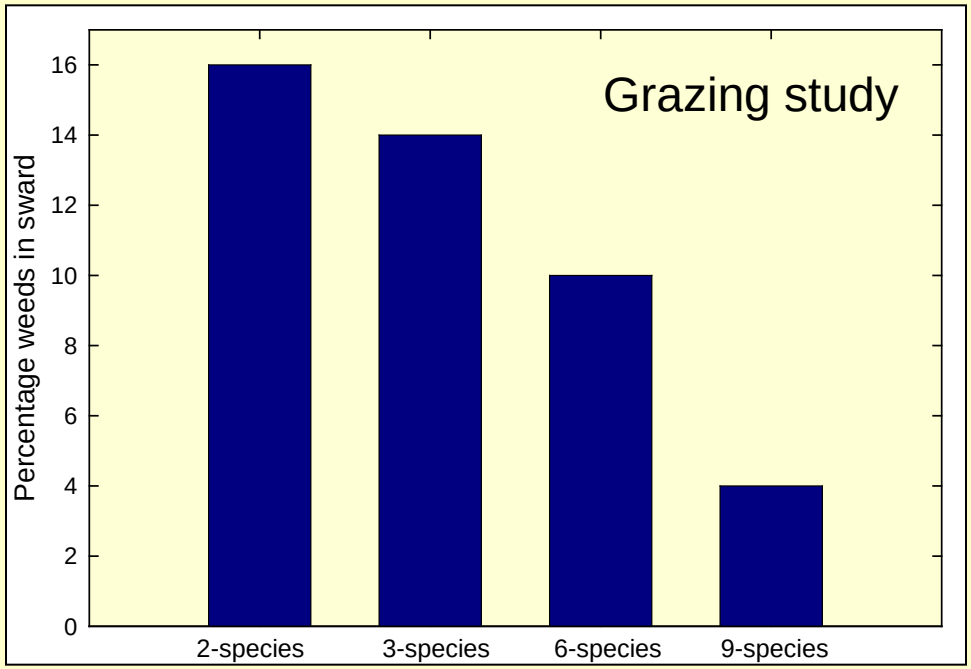
Skinner 2010. Unpublished data

Resistance to weed invasion



Greatest effect often
at establishment
Deak et al. 2009. Agron. J. 101:408

Less weed pressure in mixtures
Sanderson et al. 2005. Agron. J. 97:1465



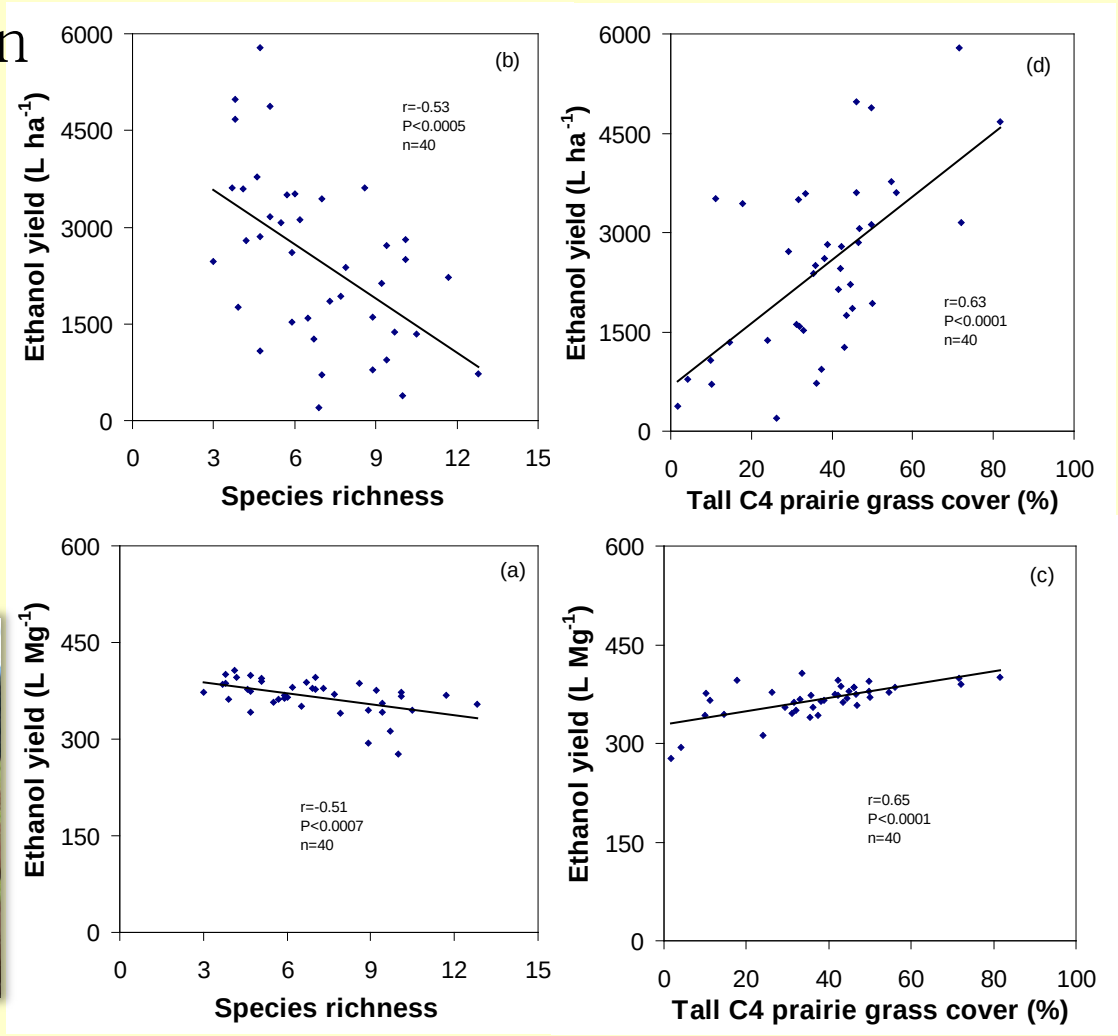
Species evenness also affects

Tracy and Sanderson. 2004. Agric. Ecosyst. Environ. 102:175
Tracy et al. 2004. Basic & Appl. Ecol. 5:543
Kirwan et al. 2007. J. Ecol. 95:530.

Survey of biofuel yields from marginal lands in the northeastern US

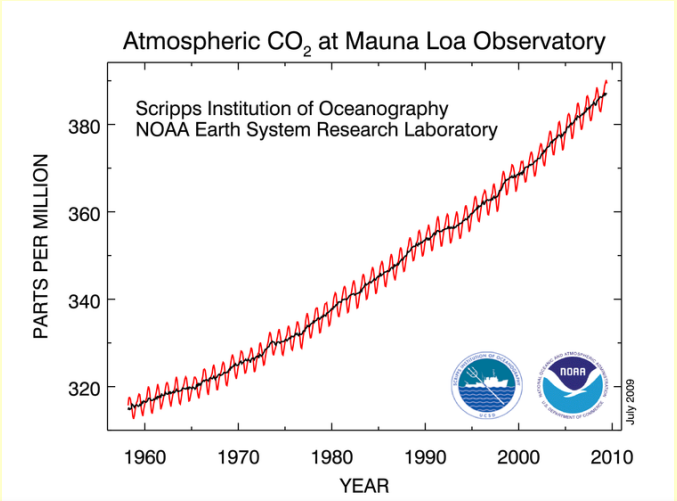
Plant species composition vs species richness effects on ethanol yield.

Adler et al. 2009. Ecol. Appl. 19:2202.

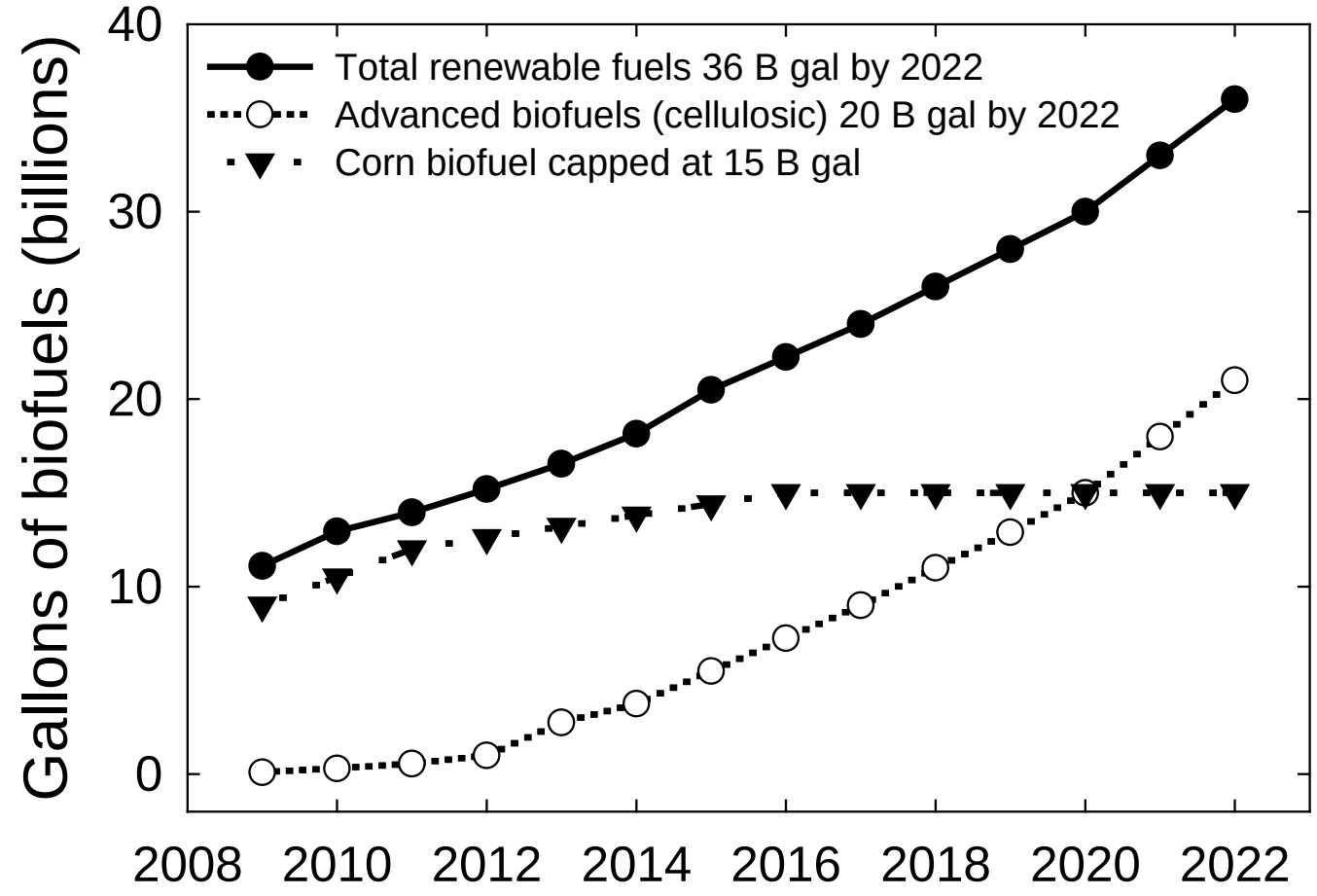


Grasslands and Biofuels

- Why the interest?
  - Global climate change
  - Enhance energy security
  - Enhance rural economies



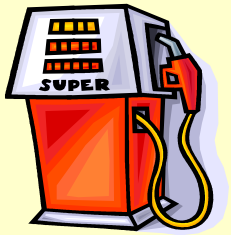
U.S. renewable fuels targets

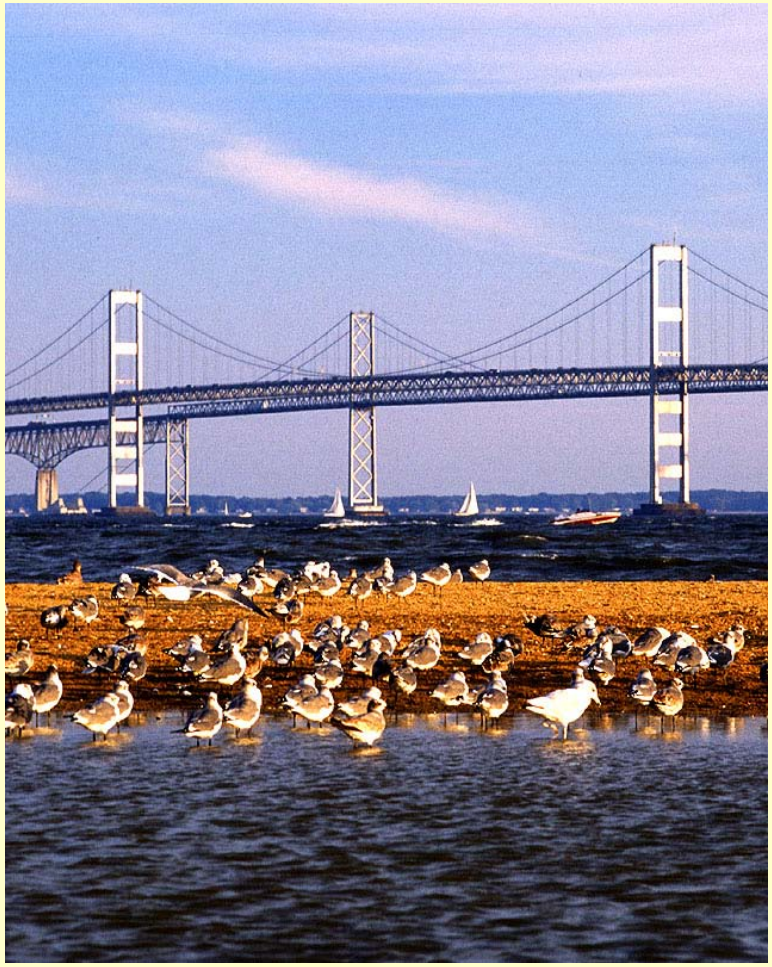


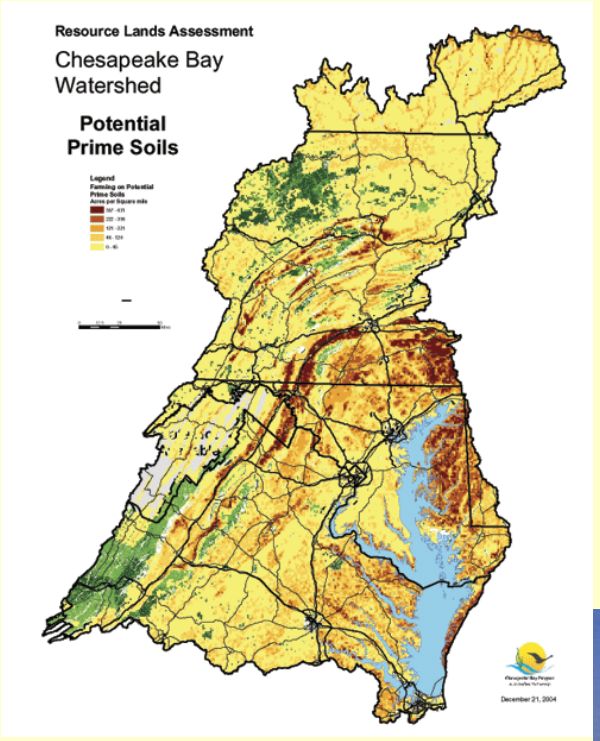
The U.S. consumes 142 billion gal of gasoline per year

Science 329:784 (13 Aug 2010)

Complex Tradeoffs

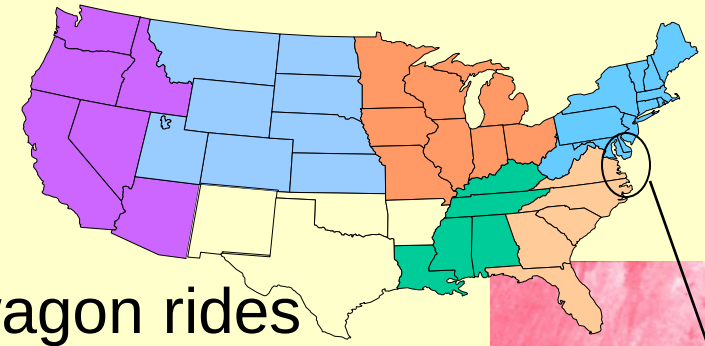






Biofuels and the Bay

Chesapeake Bay Commission
A Regional Vision for Biofuels



- "Ethanol bandwagon rides roughshod over bay"
  - ***The Bay Journal*** headline

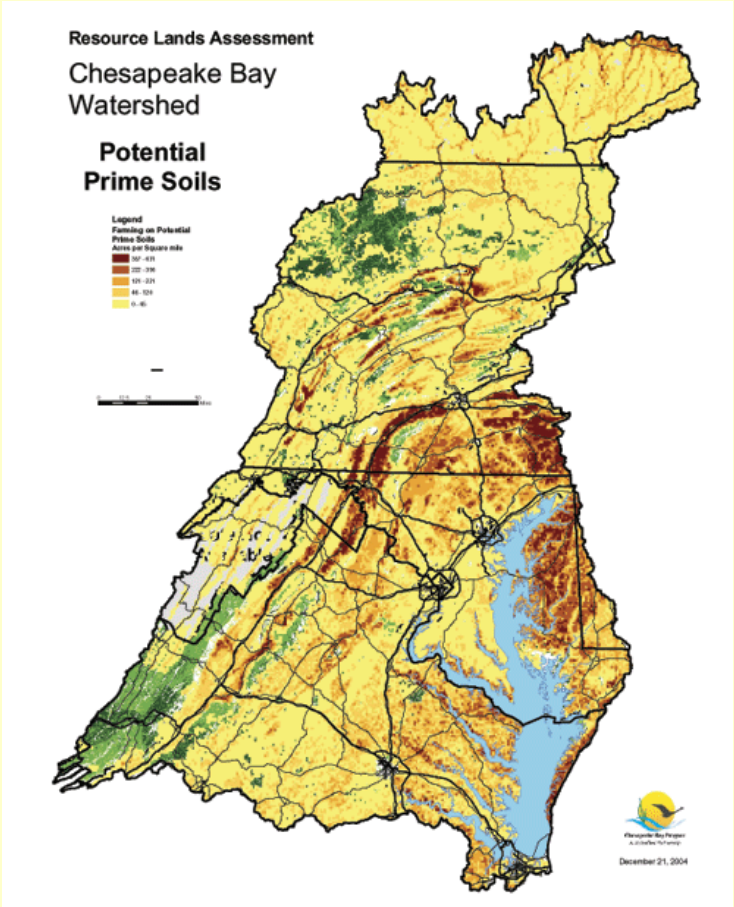
- Concern that biofuels rush could result in more corn land, more erosion, and more inputs of nutrients into the bay

Chesapeake Bay Commission. 2007. Biofuels and the bay: Getting it right to benefit farms, forests and the Chesapeake. September 2007. http://www.chesbay.state.va.us/Publications/BiofuelsAndTheBay1.pdf

Chesapeake Bay Commission
Vision for Biofuels 2007

Considered five scenarios

1. 300,000 additional acres of corn with typical management
2. 300,000 additional acres of soybean with typical management
3. 300,000 acres of switchgrass (from pasture and hayland) no fertilizer
4. 300,000 additional acres corn+cover crops
5. 1,000,000 acres switchgrass (from pasture and hayland) no fertilizer



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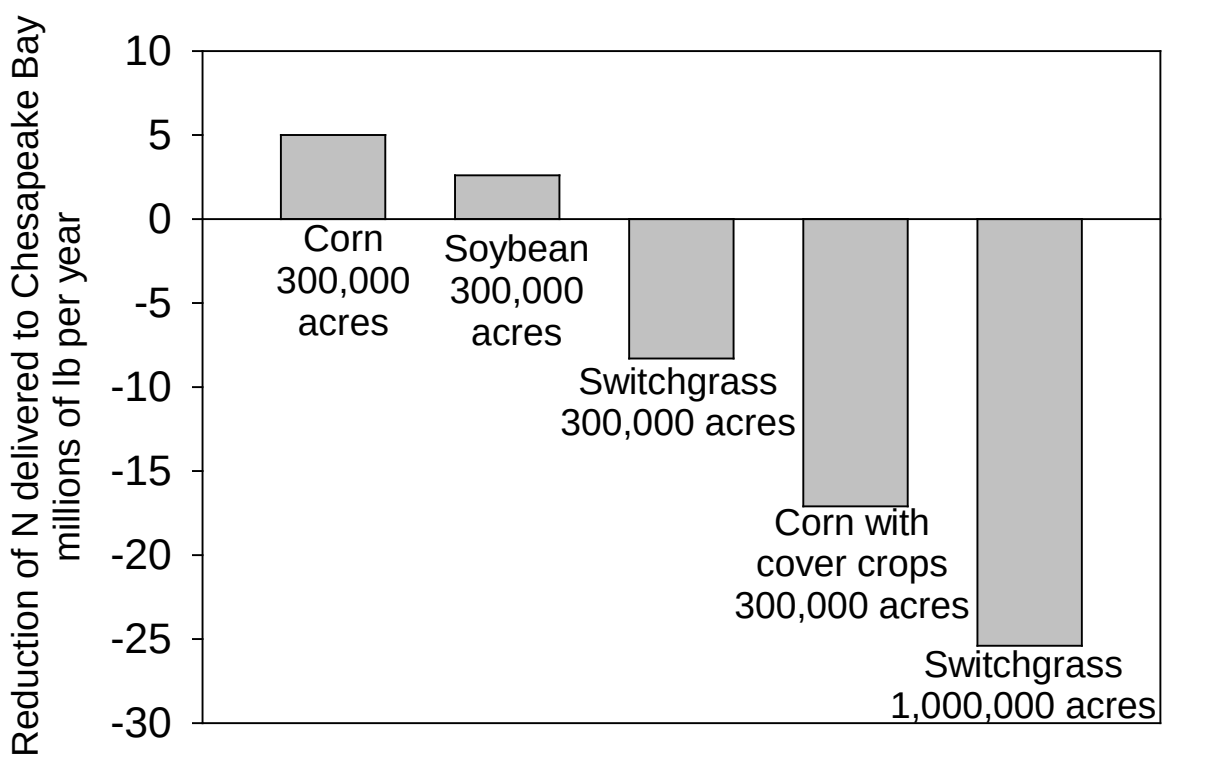
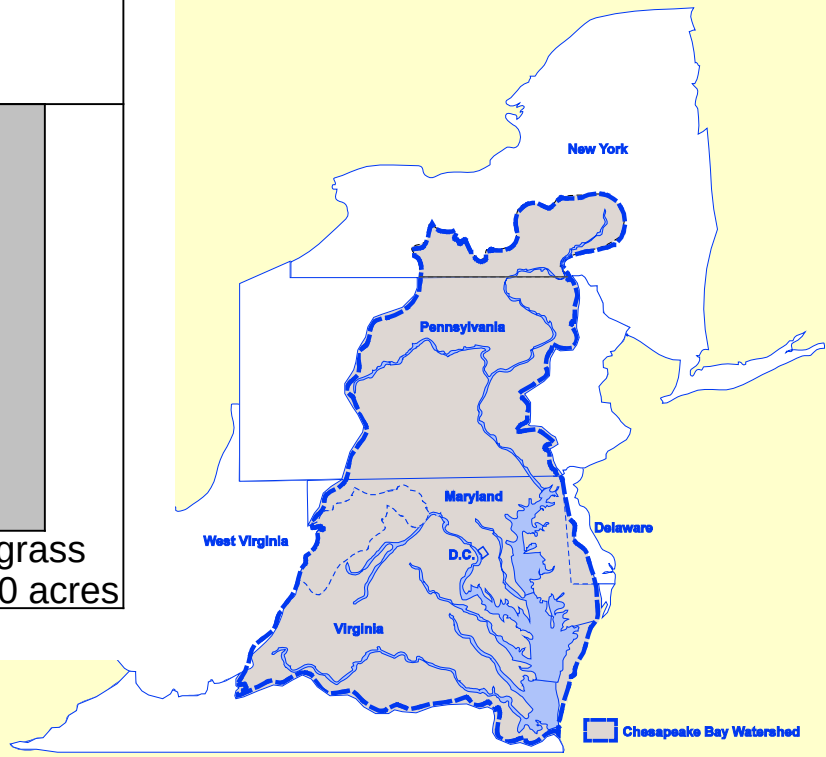
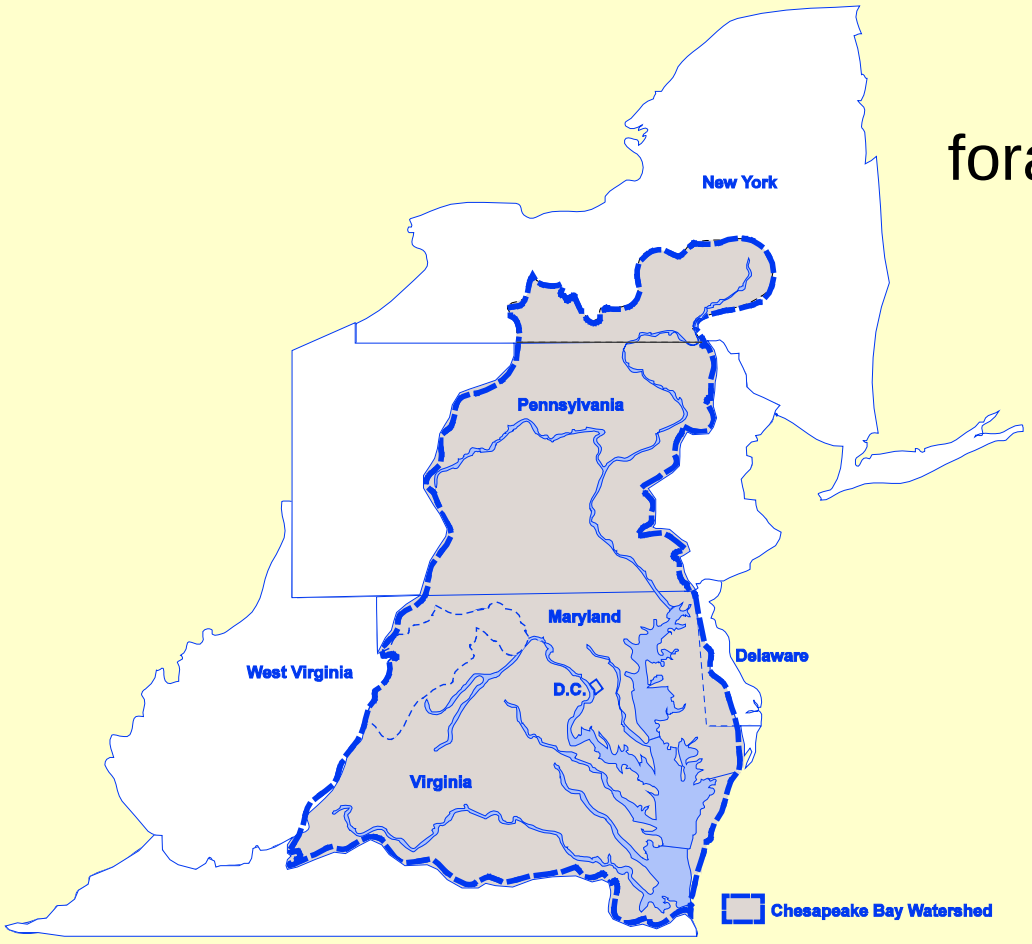




Chesapeake Bay Commission. 2007. http://www.chesbay.state.va.us/Publications/BiofuelsAndTheBay1.pdf

Chesapeake Bay Commission

Implications of original 2007report



Implications for forage-livestock agriculture?

Chesapeake Bay Commission
Revised Vision 2010

- Revised report recognized complex tradeoffs
  - Chesapeake Biofuel Policies: Balancing Energy, Economy, and Environment. 2010. http://www.chesbay.state.va.us/Publications/
  - Specifically addressed livestock sector concerns
- National visions for biofuels tend to shift acres out of forage and grazinglands
  - Will higher prices result and reduce profitability of livestock production?
  - Where will livestock go?

“We can’t grow our way out of this”

Tom Richard, Penn State

- Conservation
  - Integrated, diverse cropping systems reduce energy inputs
  - Increased fuel efficiency of cars
- New technology
  - Increased conversion efficiencies
  - Species and varieties with greater energy yields
- Suite of solutions and renewable energy sources
  - No “one size fits all” solution

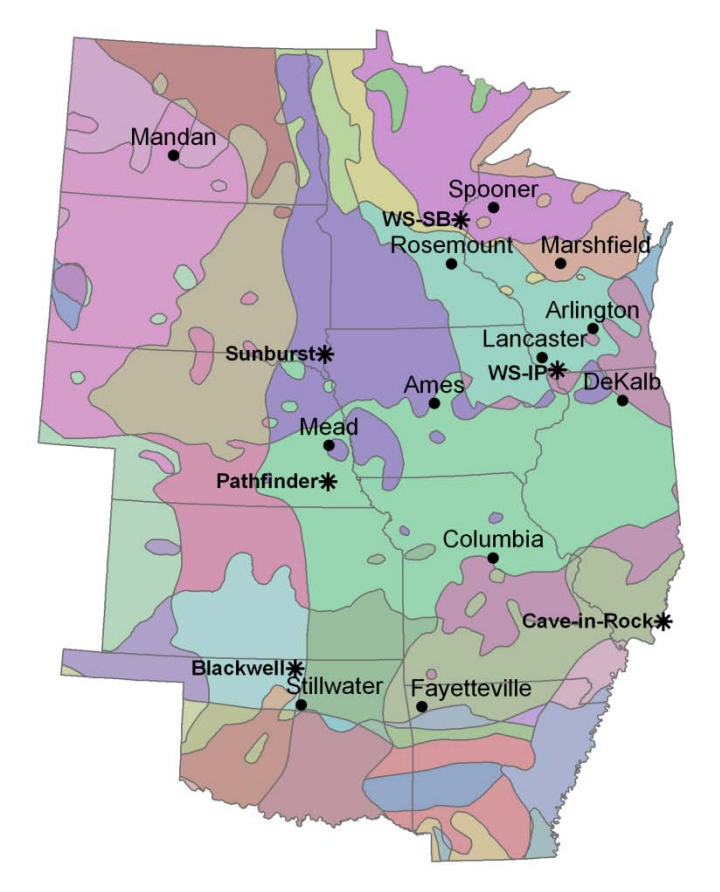
Bioenergy Cropping Systems Research at NGPRL

- **Systems Approach to Biofeedstock Production**
  - Flexible feed, forage, fuel uses
  - Farm and regional scale economics
  - National, coordinated effort in ARS
- **USDA-ARS REAP – Crop residues**
- **USDA-ARS Biomass Production Centers**
- **BioEPIC Agroecosystem Research Group**
  - NDSU-ARS partnership
  - 2 NDSU scientists located at NGPRL
  - Biomass testing lab

NDSU BioEPIC Energy and Product Innovation Center
AGROECOSYSTEM RESEARCH GROUP AT NGPRL

Northern Great Plains bioenergy crops
More than switchgrass

Plant Adaptation Regions



Region Specific Cellulosic Feedstocks

- Perennials
  - Switchgrass
  - Big bluestem
  - Indiangrass
  - Wheatgrasses
  - Perennial wildryes
  - Reed canarygrass
  - Miscanthus x gigantus
  - Prairie cordgrass
  - Hybrid poplars
  - Willows
  - False indigo
  - Alfalfa
  - Mixtures
- Annual Crop Residue
  - Corn stover
  - Cereal straw

Schmer, 2011; Vogel et al., 2005