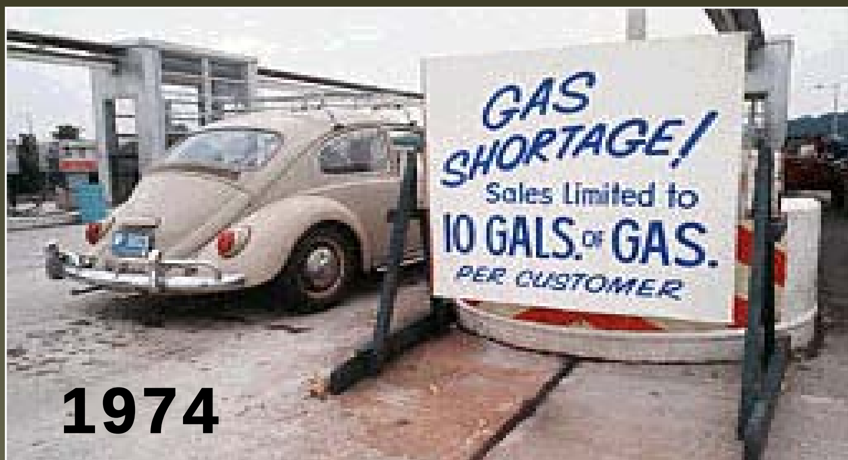
Balancing Bioenergy Opportunities on Your Natural Resource Base

Douglas L. Karlen
USDA-ARS, Ames IA

Presentation Outline

- Why is there interest in bioenergy?
- Why is there concern about bioenergy?
- How is USDA-ARS addressing these questions?
- What has cooperative field research shown?
- What are the next steps?

America's Energy Appetite



REAP

Proposed Bioenergy Plans

Plan	Goal	Time	Feedstock	Agency
Energy Policy Act of 2005	7.5 billion gal ethanol	2012	2.7 billion bu	Congress
20 in 10	20% of gasoline use (35 billion gal)	2017	12.5 billion bu (440 million tons biomass)	2007 State of the Union Message
25 x '25	25% of US energy consumption (85 billion gal + 400 billion kw)	2025	600 to 750 million tons biomass	Ag Energy Working Group
30 x '30	30% of gasoline used in 2004 (60 billion gal)	2030	1 billion tons	DOE

REAP

Erosion Cost For Grain Ethanol

The IA Natural Resources Inventory shows a soil erosion loss of 4.9 tons per acre per year

The 2005 & 2006 average corn yield was 170 bu/ac

Assume 2.7 gal EtOH/bu

Soil loss = 21 lbs/gal

Estimate developed by Duane Sand and published by the Iowa Natural Heritage Foundation, 2006

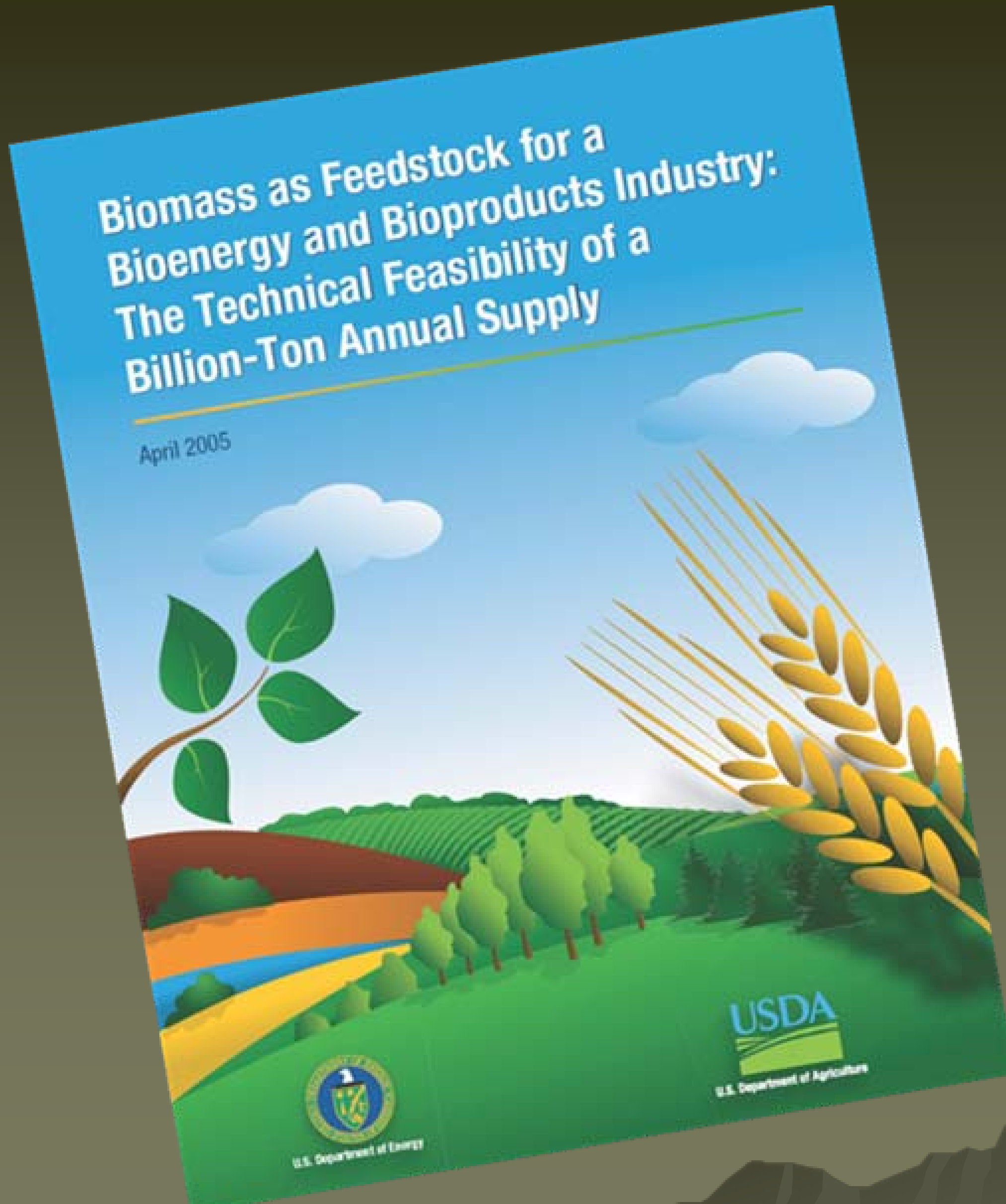
REAP

Water Quality Cost of Grain Ethanol

- 15% increase in corn acres planted in Illinois, Indiana, Iowa, Ohio, Michigan, Minnesota and Wisconsin for 2007 (NASS, 2007)
- Potential increased loss of 211 million lbs of N to streams & rivers (Elobeid et al, 2006; Wisner, 2007)
- Potential increased loss of 20 million lbs of P to streams & rivers

REAP

What Are Our Alternatives?



REAP

Biomass for Bioenergy

Forestry – 368 million tons

Agriculture – 998 million tons

- Perennial energy crops – 377 million tons
- "Wastes" – 87 million tons
- Grain – 87 million tons
- <u>Crop residues – 428 million tons</u>
  - <u>Corn stover – 256 million tons</u>

(projected estimates; Billion Ton Report, Perlack et al 2005)

REAP

Comprehending the Challenge

Football Field

If 1 ton = 1 sq in

1 billion tons = 145 football fields

Round Bales

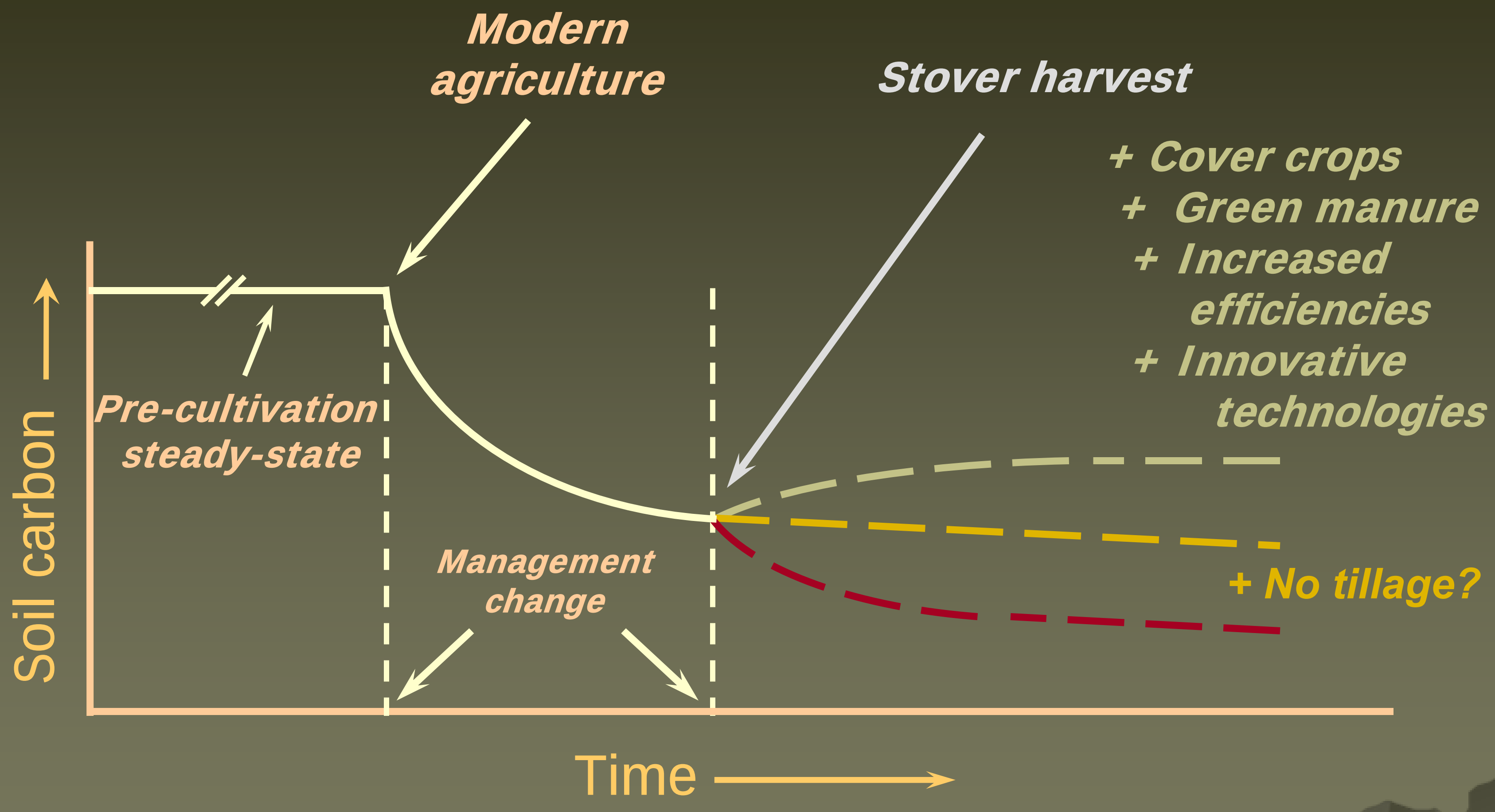
5 ft, 1000 lb, laid end-to-end

1.89 million miles

75 times around the earth

REAP

Meeting the Challenge Sustainably

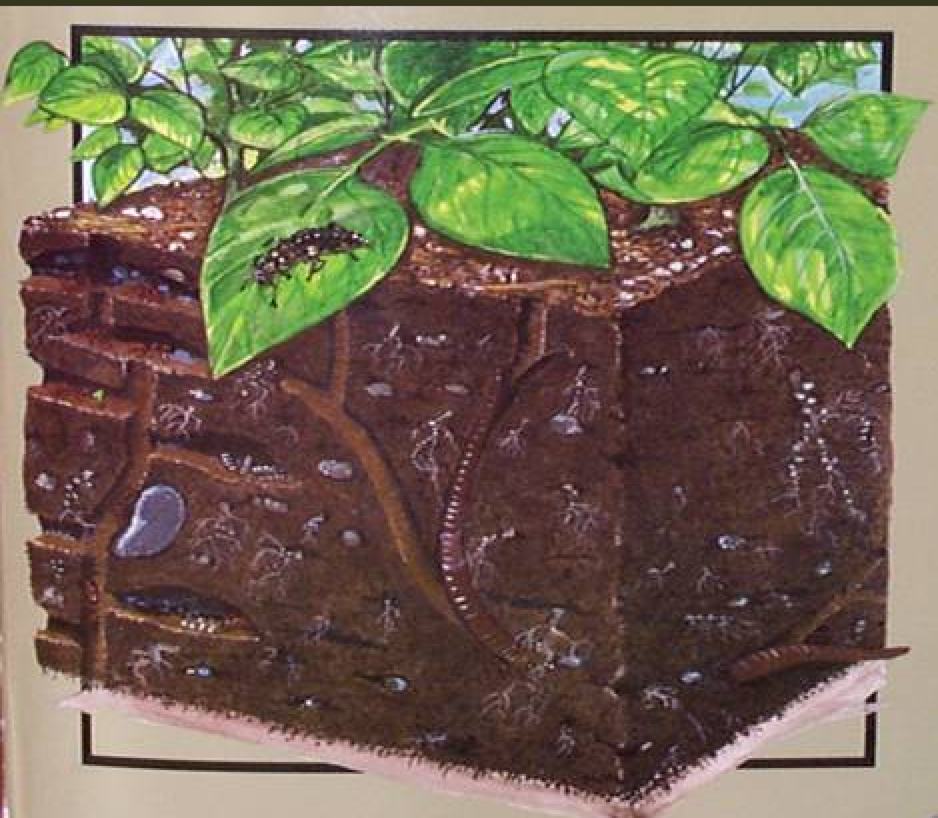


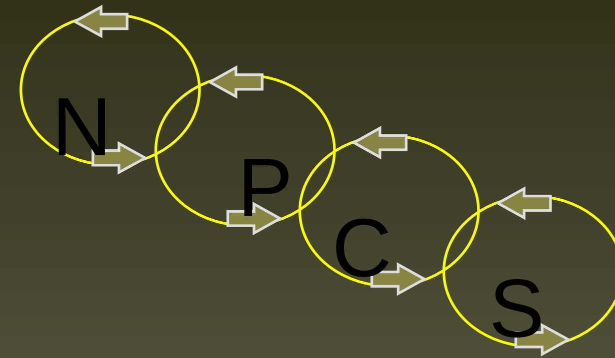
Δ ***SOC = input - output***

REAP

Crop Residues Reduce Erosion

Crop Residues Sustain Soil Life





REAP

Crop Residues & Physical Properties

REAP

Critical Take-Home Point

Crop residues are not trash!

They have multiple roles that help sustain soil resources

"Economic growth that destroys ecological support systems is neither sustainable nor truly progress"

REAP

ARS-Renewable Energy Assessment Project (REAP)

- Management practices
- Algorithms to guide sustainable harvest
- Decision support tools
  - How much residue must be retained?
  - Quantify benefits associated with retaining crop residues

VISION

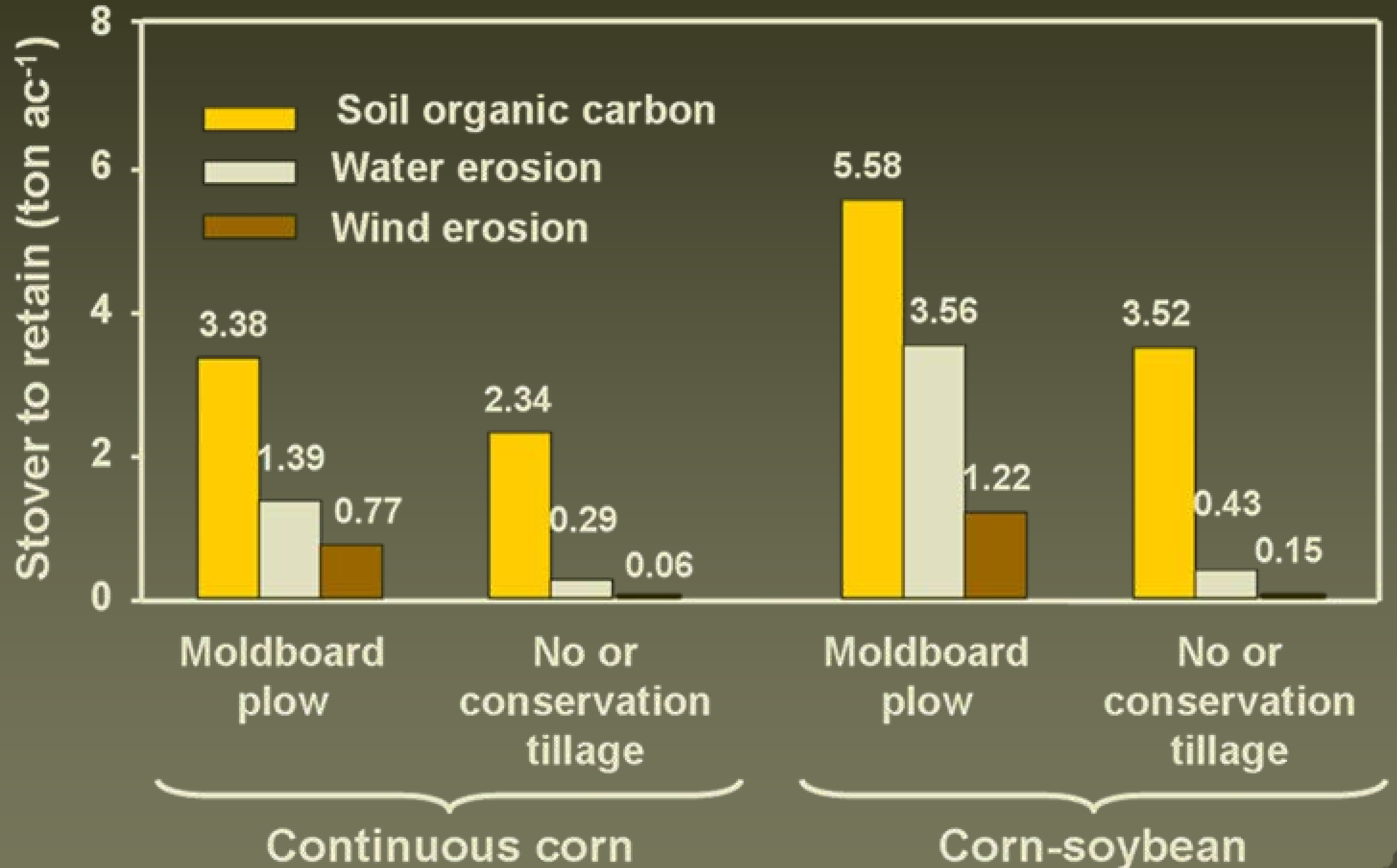
Sustainable Feedstock Production & Harvest

REAP

Biomass Harvest – Risk Analysis

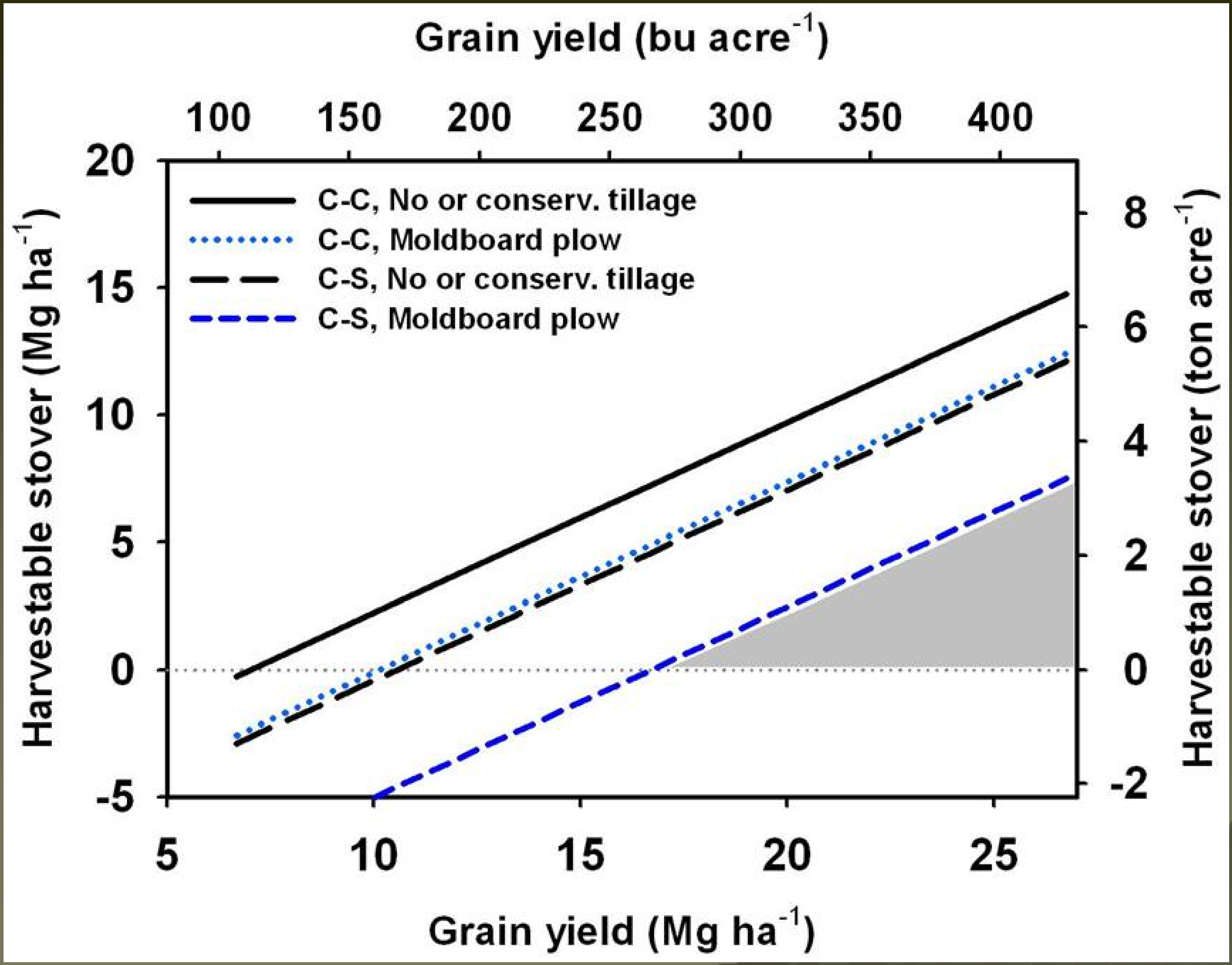
- Benefits
  - Renewable
  - Domestic
  - Reduces release of fossil CO_2
  - Additional farm commodity
- Risks
  - Decreased surface residues
  - Increased erosion
    - Off-site nutrient and sediments
  - Decreased SOM
  - Decreased productivity
  - Other – loss of winter cover, habitat

Factors Limiting Crop Biomass Removal



Wilhelm et al., Agron. J. (in press)

REAP



Grain yield (bu acre-1)
100
150
200
250
300
350
400
20
15
10
5
0
-5
Harvestable stover (Mg ha-1)
8
6
4
2
0
-2
Harvestable stover (ton acre-1)
C-C, No or conserv. tillage
C-C, Moldboard plow
C-S, No or conserv. tillage
C-S, Moldboard plow
5
10
15
20
25
Grain yield (Mg ha-1)

Initial Biomass Studies at Ames, IA

REAP

Participants and Questions

- Collaborative with Drs. S.J. Birrell (ISU) & C.W. Radtke, Idaho National Lab (DOE)
- Evaluating continuous corn & corn/soybean rotations
- Four crop residue harvest scenarios
- Nutrient removal
- Feedstock quality
- Soil quality impact

Corn Grain Yields

Continuous Corn	2005 (DKC-52-45)	2006 (P35Y61)	2007 (AgriGold 6395)
Stover Harvest Scenario	bu ac^{-1} at 15.0% moisture		
Whole plant	185	177	228
Cob & top 50%	185	174	228
Bottom 50%	184	163	225
Grain only	185	161	217
LSD $_{(0.1)}$	NS	3	10

Corn Stover Yields

Continuous Corn	2005 (DKC-52-45)	2006 (P35Y61)	2007 (AgriGold 6395)
Stover Harvest Scenario	tons ac^{-1} at 0% moisture		
Whole plant	2.10	2.82	2.43
Cob & top 50%	1.30	2.28	1.95
Bottom 50%	0.56	0.70	0.29
Grain only	---	---	---
$LSD_{(0.1)}$	0.11	0.08	0.17

Grain Yields

Rotated Corn	'05 Corn† (Fontenell 5393)	'06 Soybean‡ (Apache 626RR)	'07 Corn† (P34A20)
Stover Harvest Scenario		bu ac^{-1}	
Whole plant	226	36.6	211
Cob & top 50%	220	46.8	204
Bottom 50%	254	46.2	211
Grain only	275	52.8	205
LSD $_{(0.1)}$	30	10.1	NS

† 15.0 % water content

‡ 13.0% water content

Corn Stover Yields

Rotated Corn	'05 Corn† (Fontenell 5393)	'07 Corn† (P34A20)
Stover Harvest Scenario	tons ac^{-1} at 0% moisture	
Whole plant	3.17	3.24
Cob & top 50%	2.05	2.30
Bottom 50%	0.80	0.88
Grain only	----	----
LSD $_{(0.1)}$	0.47	0.51

Soil Test Status – Fall 2005

Indicator	Units	Management Practice	
		Cont. Corn	Rotated Corn
Total organic C	%	5.37	1.90
pH		7.72	6.68
Mehlich 3 Ext. P	ppm	32 (opt)	22 (low)
Mehlich 3 Ext. K	ppm	128 (low)	94 (low)

REAP

Macro-Nutrient Removal

Stover Harvest Scenario	Ranges for Three Hybrids ('05 & '06)		
	N	P	K
	---------- lb ac^{-1} ---------		
Whole plant	17 - 45	2 - 4	29 - 38
Cob & top 50%	12 - 28	2 - 4	23 - 28
Bottom 50%	4 - 12	0.5 - 0.7	5 - 12

Macro - Nutrient Replacement Cost

Stover Harvest Scenario	Average for Three Hybrids ('05 & '06)	
	$ ac^{-1}	$ ton^{-1}
Whole plant	$ 22.70	$ 7.84
Cob & top 50%	$ 15.52	$ 7.94
Bottom 50%	$ 5.93	$ 8.00

Secondary & Micro-Nutrients

Stover Harvest Scenario	Average Removal for Three Hybrids ('05 & '06)					
	Ca	Mg	Cu	Fe	Mn	Zn
	lb ac^{-1}		------ g ac^{-1} ------			
Whole plant	26	19	4	204	61	37
Cob & top 50%	14	10	3	123	34	27
Bottom 50%	7	5	1	87	18	8

REAP

Secondary & Micro-Nutrient Replacement Cost

Stover Harvest Scenario	Average Replacement Cost ('05 & '06)	
	$ ac^{-1}	$ ton^{-1}
Whole plant	$ 5.00	$ 1.84
Cob & top 50%	$ 2.95	$ 1.54
Bottom 50%	$ 1.47	$ 2.08

REAP

Total Nutrient Replacement Cost

Stover Harvest Scenario	Average for Three Hybrids ('05 & '06)		
	$ ac^{-1}	$ ton^{-1}	$ gal $EtOH^{-1}$
Whole plant	$ 27.71	$ 9.67	$0.121†
Cob & top 50%	$ 18.47	$ 9.49	$0.118
Bottom 50%	$ 7.39	$ 10.10	$ 0.126

† Assumes 80 gal EtOH ton^{-1} biomass

REAP

What's Next?

Multiple biomass sources
Many new technologies
Emphasis on conservation
Refinement of expectations
Asking & answering the right question

Efficient Bioenergy Production Will Require All Disciplines

- Agronomy
  - Continuous green cover
  - Optimize planting patterns, cultivars, and cultural practices
- Soil science
  - Improve water and nutrient use efficiencies
  - Precision input application
- Crop breeding
  - Improve quality
  - Enhance stress tolerance
- Physiology/morphology
  - Canopy structure
  - Root structure and function
- Biochemistry
  - Modify metabolic pathways
  - Eliminated inefficiency (photorespiration)
- Genetic engineering
  - Make C_3 species as C efficient as C_4 species
  - Use green light
  - Use all energy in photons

REAP

Diversity Can Make Us All Winners

- Ligno-cellulosic technologies can provide viable markets for a wide variety of crops

- Landscape diversity can help solve bioenergy, air quality, water quality, global warming (through C sequestration) & rural economic problems – IF implemented as an entire agricultural system.

REAP


Crop residues are not WASTES,
waiting to be used productively.
They are used NOW, and have been
for centuries, as the PRIMARY soil
amendment providing input of carbon
and nutrients that are essential for
sustained production of food, feed,
fiber–and now FUEL.
REAP