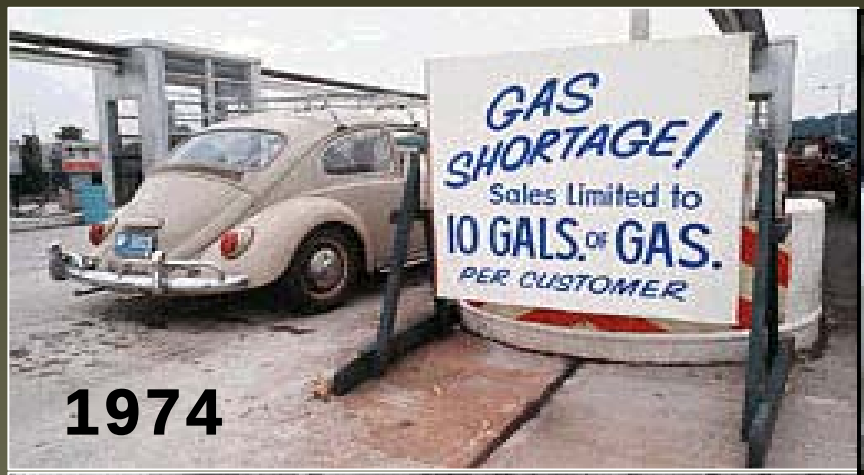
Crop Residue – What's It Worth?

Douglas L. Karlen and Stuart J. Birrell
USDA-ARS & Iowa State University

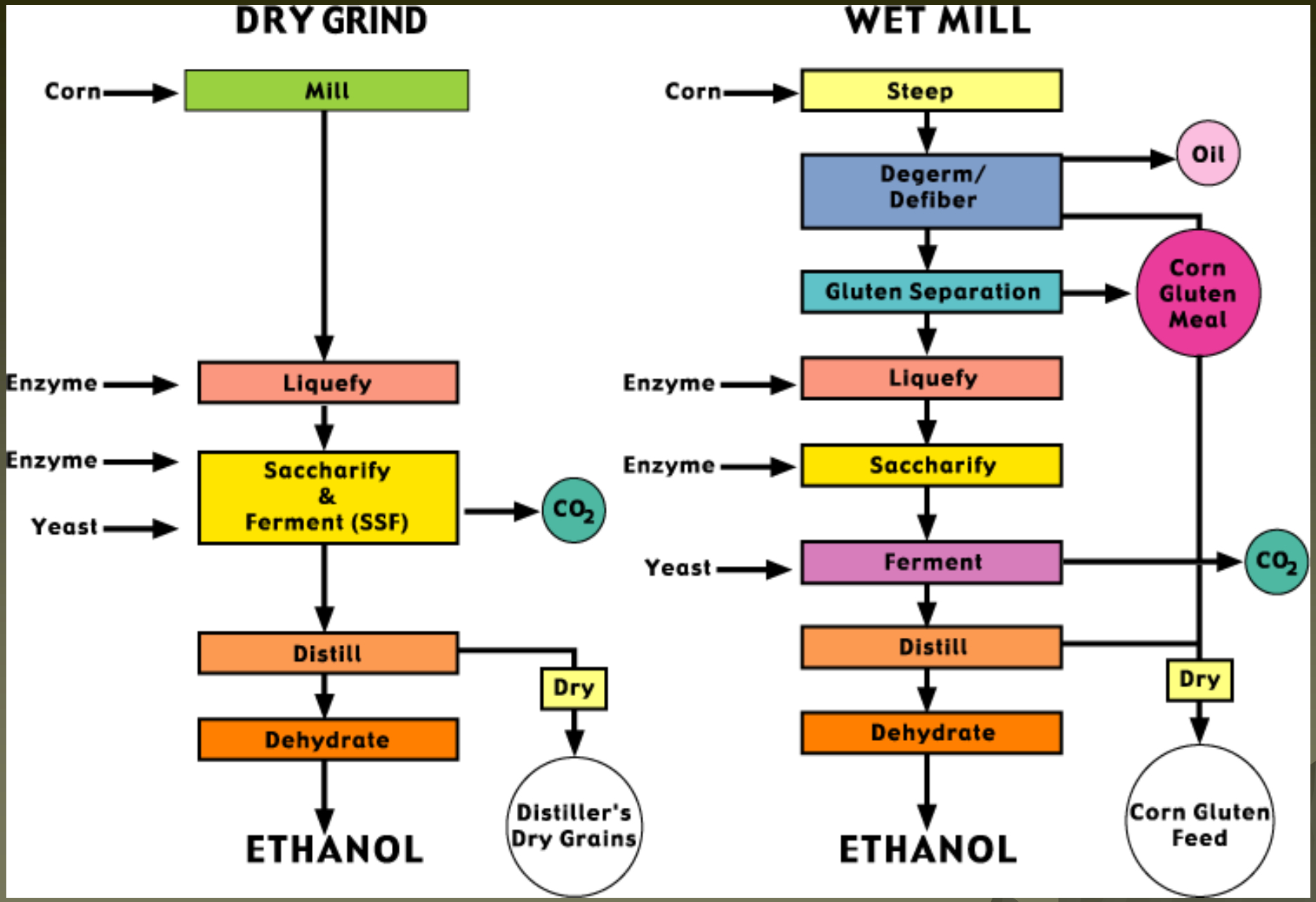
Presentation Outline

- Why is there interest in crop residue?
- Why is there concern about crop residue?
- How is USDA-ARS addressing these questions?
- What has renewed research shown?
- What are the next steps?

America's Energy Appetite



REAP



80 % of Current Production

20 % of Current Production

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

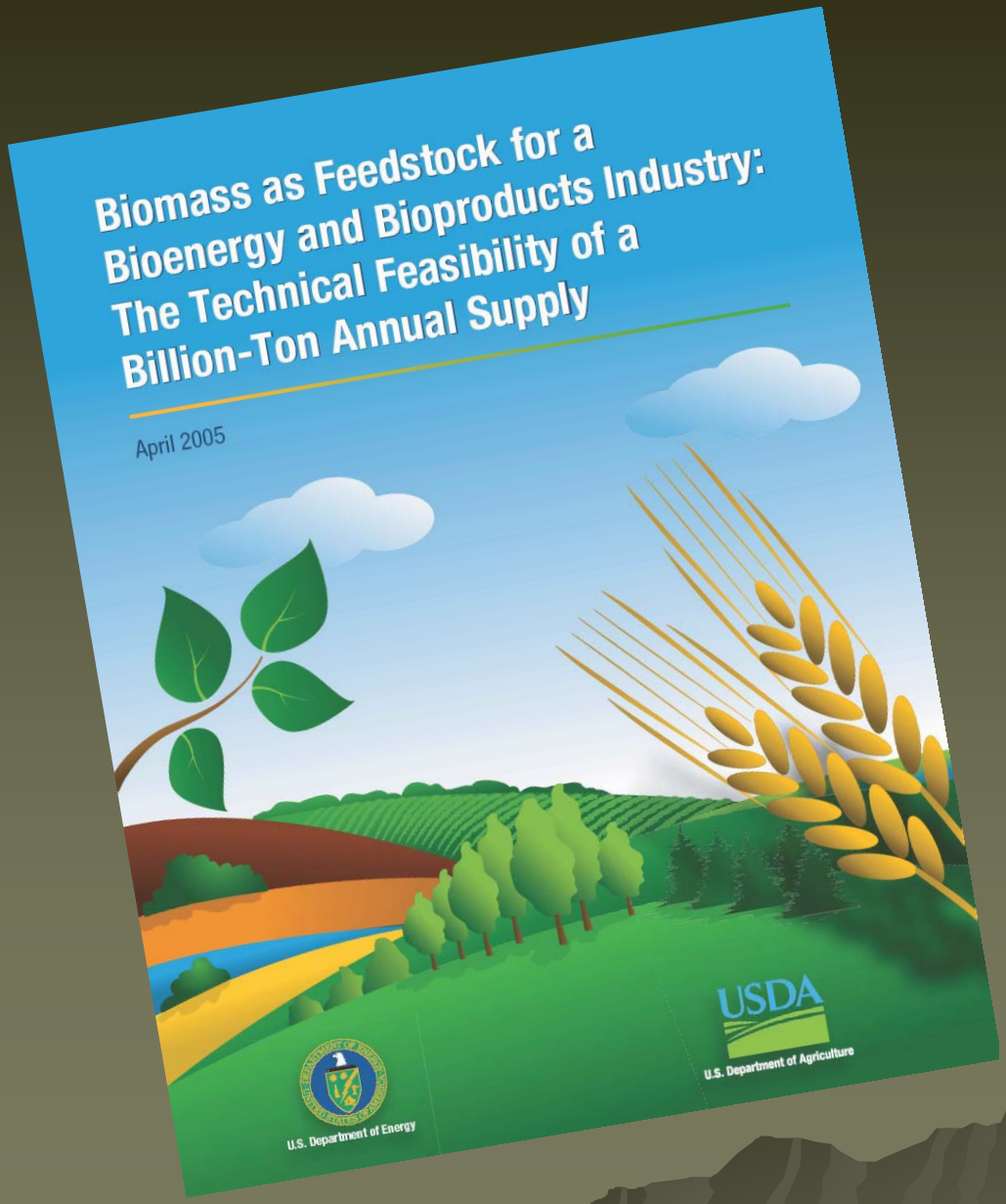
Estimate developed by Duane Sand and published by the Iowa Natural Heritage Foundation, 2006

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

What Are Our Alternatives?



REAP

Biomass for Bioenergy

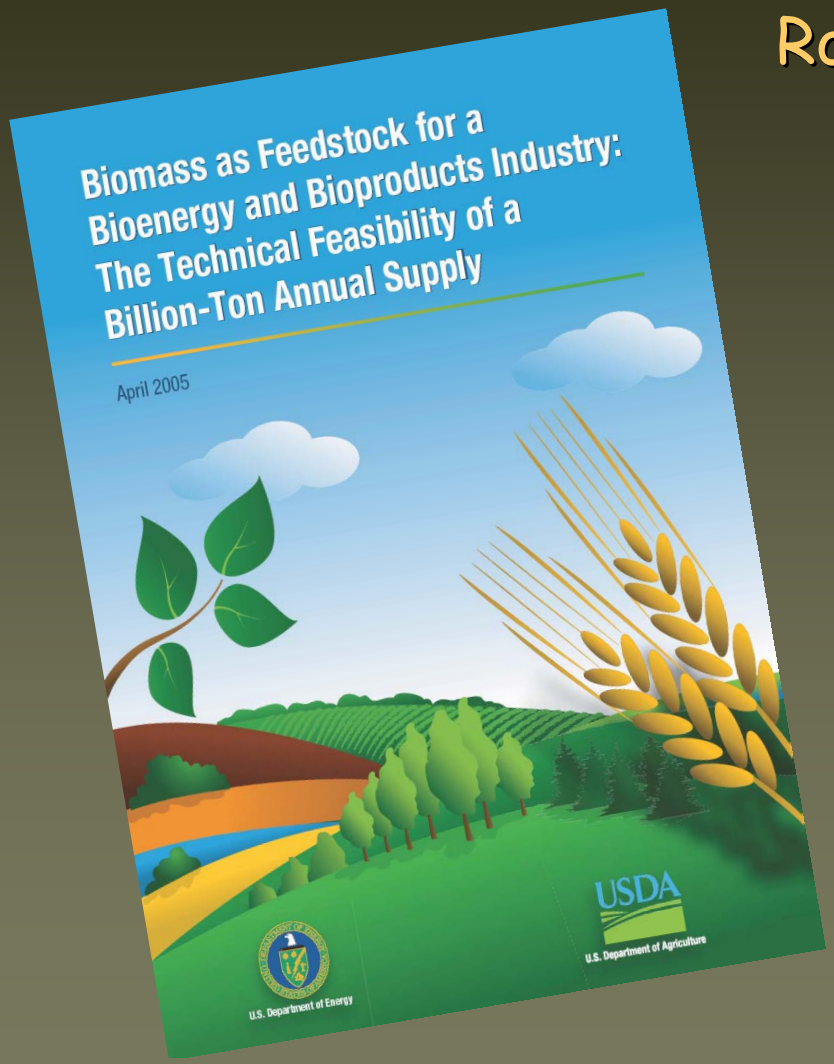
Forestry – 368 million tons

Agriculture – 998 million tons

- Perennial energy crops – 377 million tons
- "Wastes" – 87 million tons
- Grain – 87 million tons
- **Crop residues – 428 million tons**
  - **Corn stover – 256 million tons**

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

Comprehending the Challenge



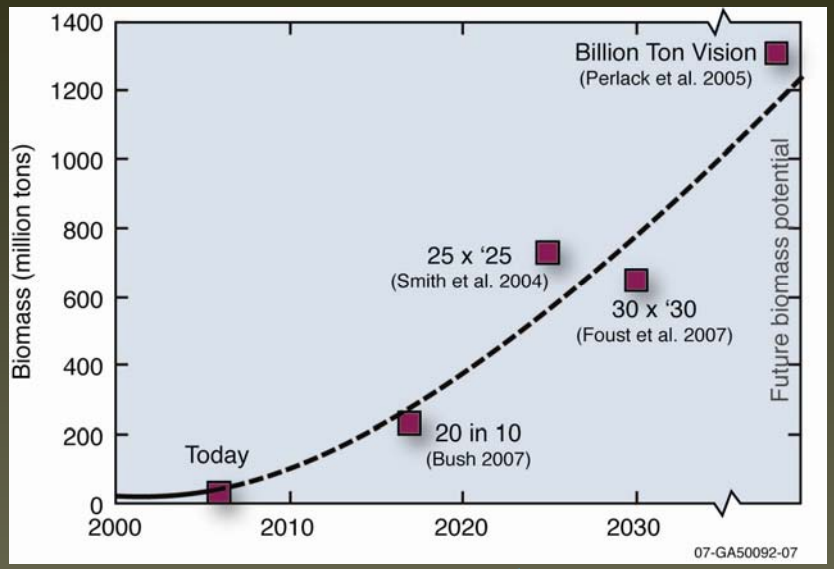
Row of 1000 lb round bales, 5 ft long, placed end-to-end; = 1.89 million miles or (75 times around the earth)

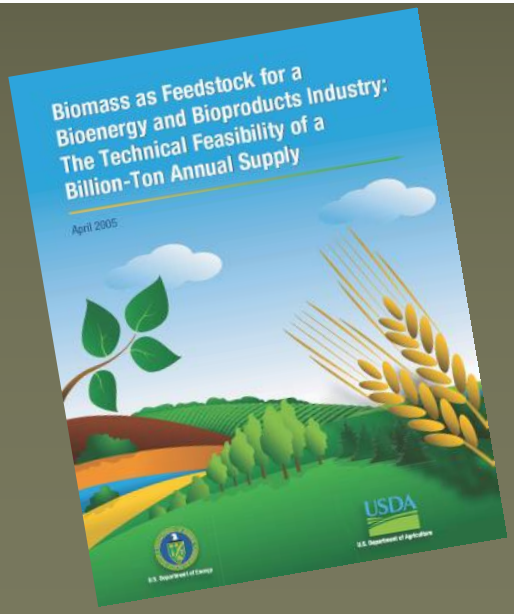
If one ton = 1 sq in

1 billion tons = 145 football fields

REAP

What's Needed for a Billion Tons?





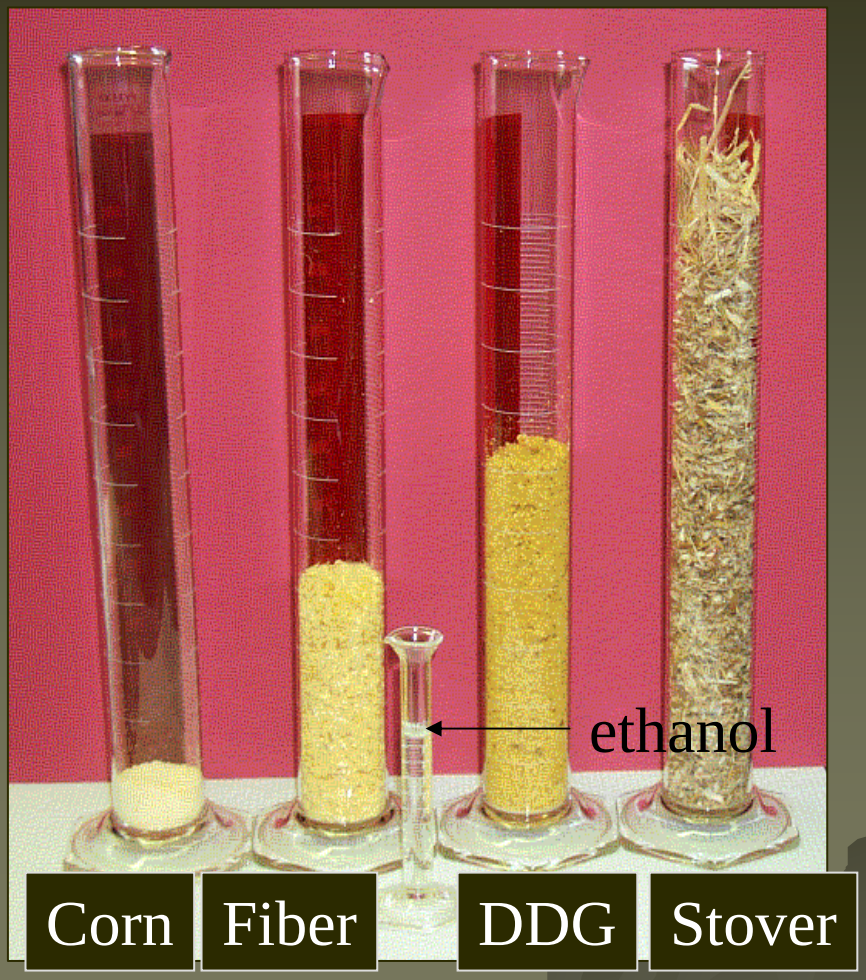
- Sustainably produce ONE BILLION TONS of feedstock annually
  - Yield increase 50% by 2030
    - Corn and small grains
  - Residue/grain ratio for soybean increase from 1.5:1 to 2.0:1
  - Machine to recover 75% stover
  - No tillage adopted universally

REAP

Density Effects for 10 ml Ethanol

Research Challenges

- Low density feedstock
- Costly pretreatment
- Inefficient enzymes
- New biocatalysts needed
- Low co-product value
- Product recovery



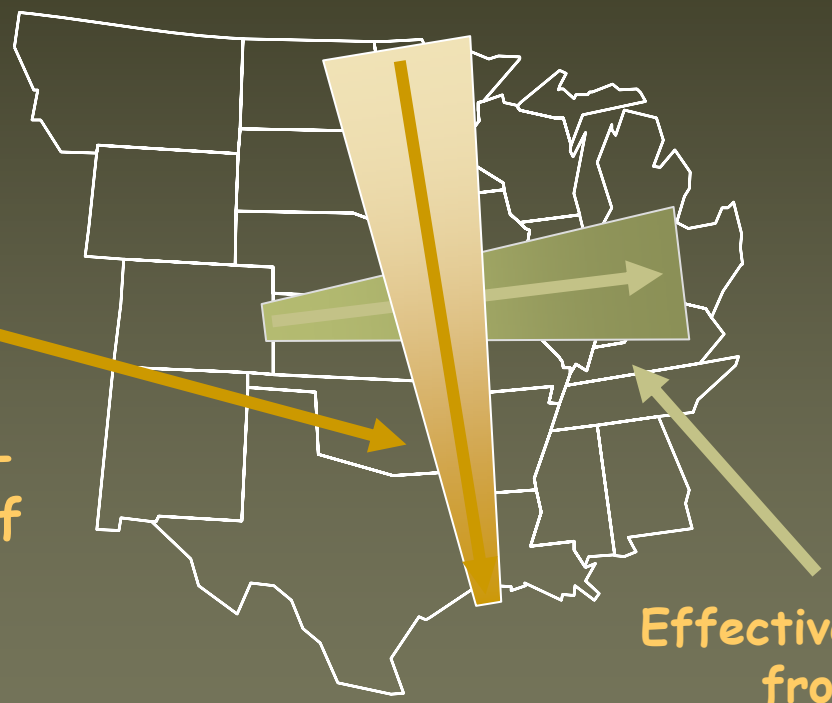
Environmental Concerns

- Erosion
  - Water
  - Wind
- Loss of SOC
  - Cycling of C and nutrients
  - GHG
- Water quality
- Others
  - Energy balance
  - Products of combustion
  - Public opinion

Climate and Weather Interactions

- Climate and weather impact rate of residue conversion to SOC and retention of SOC

Average temperature increases from north to south
-SOM decreases-
(primary effect of temperature)



Effective moisture increases from west to east
-SOM increases-
(primary effect of NPP)

Brady. 1992.

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

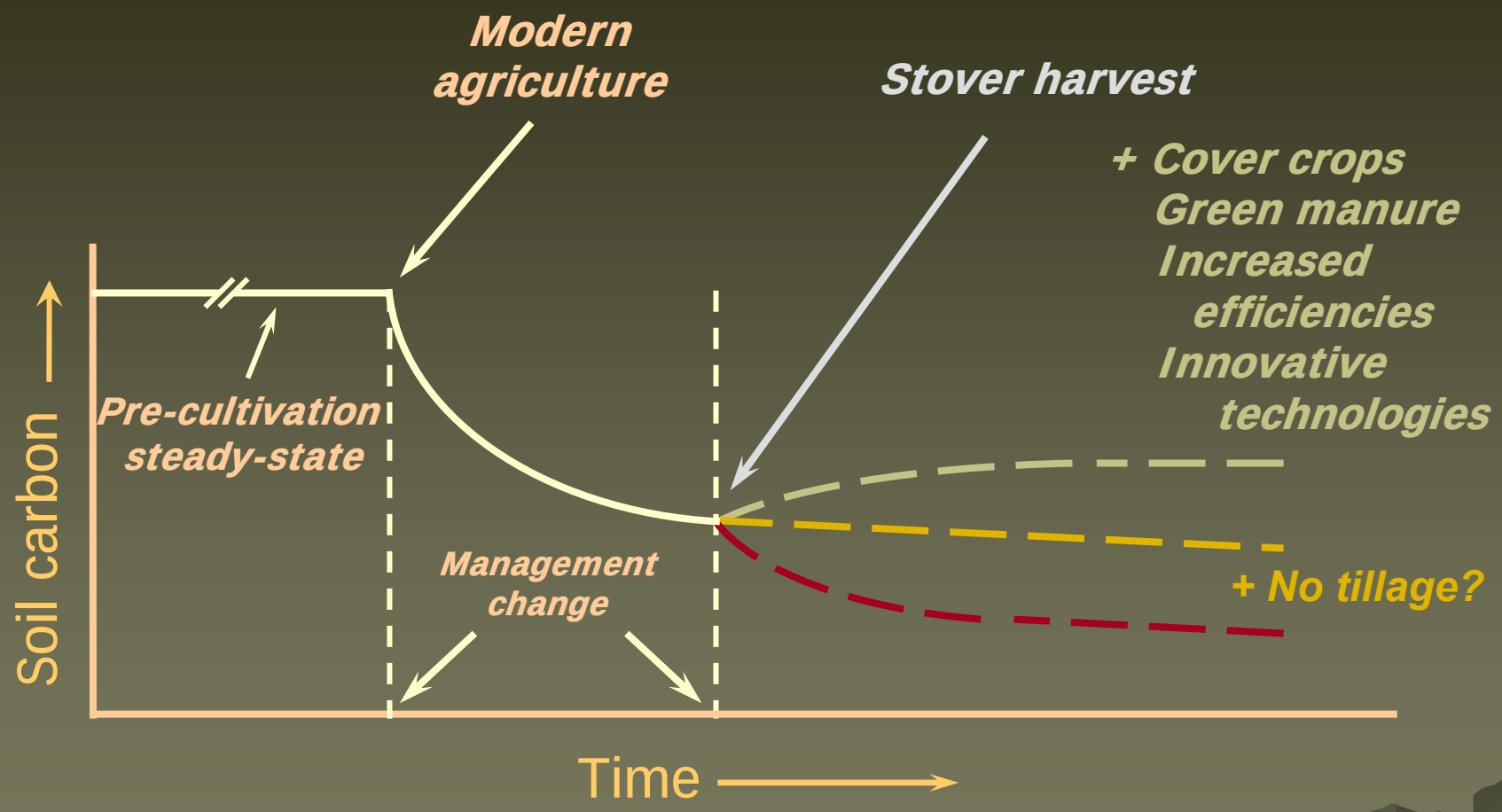
REAP

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

REAP

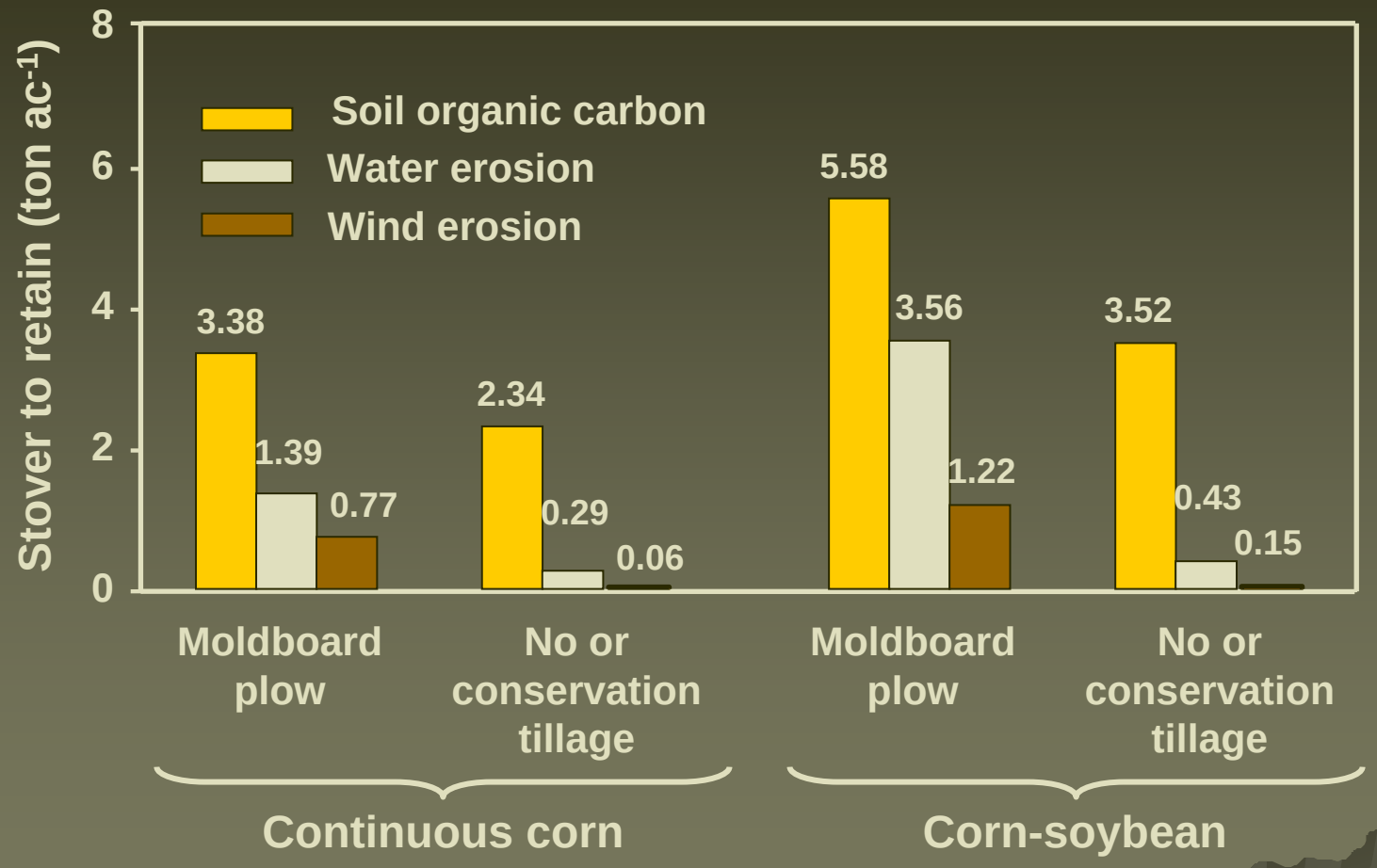
Meeting Expectations Sustainably



Δ SOC = input - output

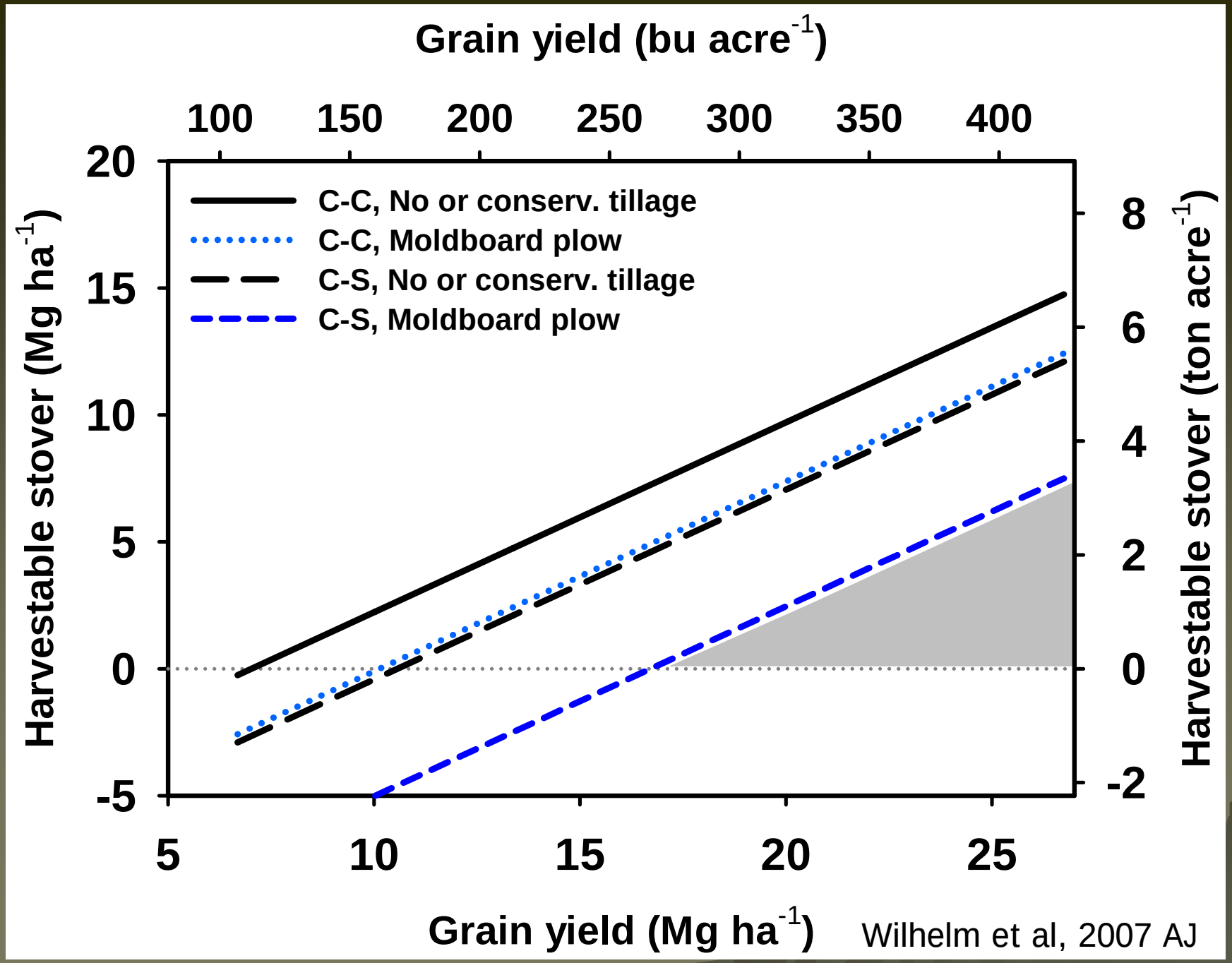
REAP

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
8
6
4
2
0
-2
C-C, No or conserv. tillage
C-C, Moldboard plow
C-S, No or conserv. tillage
C-S, Moldboard plow
Harvestable stover (Mg ha-1)
Harvestable stover (ton acre-1)
5
10
15
20
25
Grain yield (Mg ha-1)
Wilhelm et al, 2007 AJ

Initial Biomass Studies at Ames, IA

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

REAP

Corn Grain & Stover Yields

Continuous Corn	2005 (DKC-52-45)		2006 (P35Y61)	
Stover Harvest Scenario	Grain bu ac^{-1}	Stover ton ac^{-1}	Grain bu ac^{-1}	Stover ton ac^{-1}
Whole plant	161	2.10	154	2.82
Cob & top 50%	161	1.30	151	2.28
Bottom 50%	160	0.56	142	0.70
Grain only	161	----	140	----
$LSD_{(0.1)}$	NS	0.11	3	0.08

REAP

Corn Grain & Stover Yields

Rotated Corn	'05 Corn (Fontenell 5393)		'06 Soybean (Apache 626RR)	
Stover Harvest Scenario	Grain bu ac^{-1}	Stover ton ac^{-1}	Grain bu ac^{-1}	Stover ton ac^{-1}
Whole plant	197	3.17	32.4	----
Cob & top 50%	192	2.05	41.4	----
Bottom 50%	221	0.80	40.9	----
Grain only	239	----	46.7	----
LSD $_{(0.1)}$	26	0.47	8.9	----

REAP

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		
	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	
	$ ac^{-1}	$ ton^{-1}
Whole plant	$ 22.70	$ 7.84
Cob & top 50%	$ 15.52	$ 7.94
Bottom 50%	$ 5.93	$ 8.00

REAP

Secondary & Micro-Nutrients

Stover Harvest Scenario	Average Removal for Three Hybrids					
	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	
	$ 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		
	$ 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, and answering, the

Increased efficiency… Increased pool of reduced C

- 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
  - Convert C_3 species to C_4
  - 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