BESS Model:
Biofuel Energy Systems Simulator

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Need to get corn-ethanol right

- **Rapid expansion of production capacity**
  - **60% of current capacity from plants that have come on line since January 2005; 75% by end of 2009**
- **Actual direct-effect fossil fuel use and emissions can be obtained from commercial-scale operations (crop systems, biorefineries)**
  - **Important to use values consistent with industry performance as it currently functions**
  - **Exception: nitrogen losses (can use IPCC defaults)**
- **Indirect effects difficult to estimate and highly uncertain**
  - **At what volume of production (15, 18, or 30 bgy?)**
  - **Currency exchange rates, land use policies, rate of crop yield gains on existing farm land?**

Biofuel Energy Systems Simulator (BESS)

- **<u>Scope:</u> corn-ethanol dry mill biorefineries; 8 default scenarios; can be customized for an individual facility**
- **<u>Co-product credit:</u> substitution method**
- **<u>Not covered:</u> wet mill corn-ethanol facilities (18% of 2006 capacity but decreasing rapidly)**
- **<u>Parameters assessed:</u> GHG emissions, net energy, direct resource requirements (land, water, nitrogen, other nutrients, fossil fuels), soil C sequestration**
- **<u>Land use change:</u> not assessed, but could be added as a single GHG "debt" for entire industry**
- **<u>Data sources & defaults:</u> USDA-NASS and -ERS, recent industry surveys and state agency reports, IPCC emission factors**
- **<u>Future work:</u> cellulosic ethanol from switchgrass and corn residue, biomass-powered corn-ethanol plant, sweet sorghum ethanol**

Biofuel Energy Systems Simulator (BESS)

- **Updated estimates for direct-effect GHG emissions of corn ethanol based on best current science and input from all key disciplines (engineers, agronomists, soil scientists, animal nutritionists, industry professionals)**
- **User-friendly, completely transparent, and well documented**
- **Default scenarios based on regional-scale data, but can also be used for certification of an individual ethanol plant, its associated corn supply and co-product use**
- **Can be used to estimate carbon-offset credits for emissions trading whereby an individual ethanol plant serves as the aggregator for the entire life-cycle**
- **Can be used for compliance and certification if it is consistent with LCFS standards**

Input data for BESS default scenarios

Corn Production

- USDA-ERS *ARMS* crop inputs 2005; energy inputs from 2001

  (Surveys of corn production energy inputs no longer conducted - William McBride, USDA-ERS)
- USDA-NASS state crop yields, 3-yr average, 2003-2005
- UNL production-scale data, irrigated corn (Carbon Sequestration Project, Mead) for high-yield progressive scenario (**Verma et al, 2005**)

Biorefinery

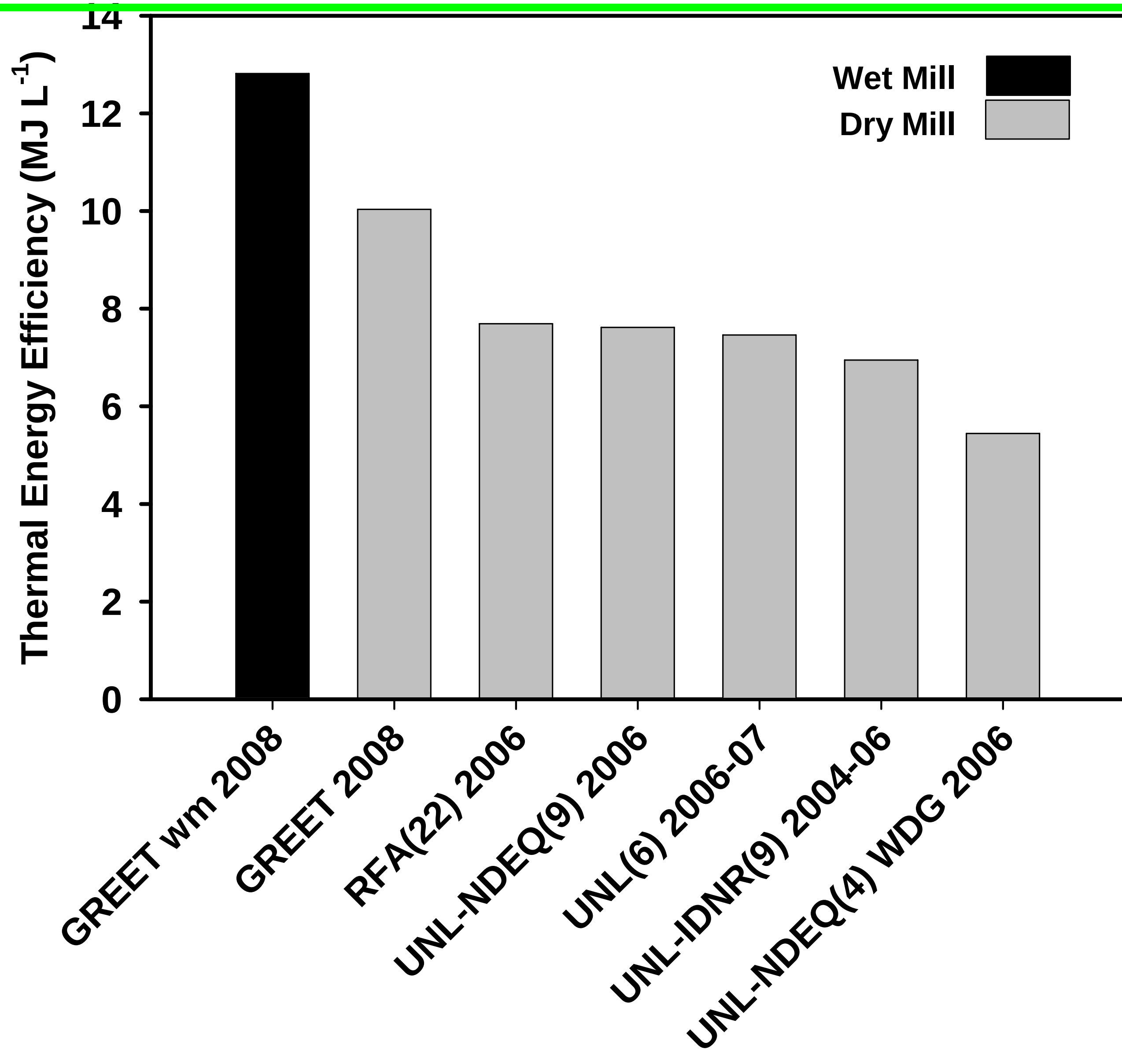
- Four recent industry surveys with data for natural gas use, electricity use and corn-to-ethanol conversion efficiency
- PrimeBiosolutions, Mead NE, closed-loop biorefinery system

Co-product cattle feeding: co-product model based on Klopfenstein, 2008; additional manuscripts in progress

Greenhouse Gas Emission factors

- *IPCC 2006 Guidelines for National Greenhouse Gas Inventories.*
- EPA, *e-grid 2004,* state avg. (**see BESS *User's Guide* for more details**)

Biorefinery thermal energy efficiency: Previous natural gas estimates vs. RFA & UNL surveys, NE & IA state records



Default scenarios in BESS model: for different cropping regions and biorefinery types

Scenario #	Crop production region	Biorefinery energy (dry mill)	Co-product type	NEW Survey Data
1	USA Midwest Avg.	natural gas-MW	mix dry-wet DGS	RFA-22
2	USA Midwest Avg.	natural gas-MW	mix dry-wet DGS	UNL-6
3	Iowa Avg.	natural gas-IA	mix dry-wet DGS	IDNR-9
4	Nebraska Avg.	natural gas-NE	mix dry-wet DGS	NDEQ-9
5	Nebraska Avg.	natural gas-NE	Wet DGS	NDEQ-4
6	Nebraska Avg.	NG, closed-loop	Wet DG	NDEQ-4
7	Nebraska Avg.	coal	Dry DGS	EPA
8	Progressive cropping (CSP)	natural gas-NE	mix dry-wet DGS	NDEQ-9

Crop production inputs (BESS scenarios)

		US avg.	IA avg.	NE avg.	High Yield
Grain Yield	Mg ha-1	9.47	10.7	9.73	13.71
N Fertilizer	kg N ha-1	150	144	146	177
Manure N	kg N ha-1	6	5	6	-
P Fertilizer	kg P2O5 ha-1	53	53	34	-
K Fertilizer	kg K2O ha-1	62	67	6	-
Lime	kg ha-1	254	334	86	-
Herbicides	kg ha-1	6	5	7	2.2
Insecticides	kg ha-1	0.3	0.1	0.6	0.2
Seed	kg ha-1	20	21	19	30
Gasoline	L ha-1	16	11	20	-
Diesel	L ha-1	57	43	116	40
LPG	L ha-1	45	67	38	-
Natural Gas	m^3 ha-1	28	-	67	-
Electricity	kWh ha-1	98	42	377	1332

Go to BESS simulation mode:

Comparison of four scenarios-

1. NE coal dry distillers grains
2. NE natural gas average
3. NE natural gas wet DDGS
4. NE natural gas, wet DDGS, improved crop management

Influence of cropping system and biorefinery type on GHG emissions reduction: %, Mg CO2e*

20% reduction for 2007 EISA RFS

Corn Production System

Ethanol Biorefineries

	USA-MW average	Iowa average	NE average	Advanced Irrigated
coal	24%, 179,000	26%, 187,000	21%, 153,000	25%, 186,000
natural gas†	**54%, 395,000**	**57%, 420,000**	**50%, 371,000**	55%, 405,000
natural gas, wet DG	64%, 469,000	64%, 468,000	**60%, 444,000**	64%, 474,000
closed-loop facility	72%, 526,000	72%, 529,000	68%, 498,000	73%, 534,000

*Based on a 100 million gal yr-1 production capacity, †average based on surveys

BESS model results, vers. 2008.3.0, www.bess.unl.edu

Corn-ethanol GHG emissions from different life-cycle models

Life-cycle GHG emissions intensity from dry-mill corn-ethanol (gCO2e/MJ)					
Emissions	GREET	EBAMM	BEACCON	BESS (1)	BESS (5)
Crop	44	37	44	30	33
Biorefinery	43	64	37	31	25
CP CREDIT	-17	-25	-17	-19	-24
Denaturant	-	-	6	-	-
Land use change	(*104*)	-	1	-	-
GWI	70	76	71	43	35
Gasoline	92	92	92	92	92
GHG reduction, %	24	17	23	54	62

GREET vs.1.8a: land use change from Searchinger et al. Science 2008
EBAMM: vs.1.1-1: Farrell et al. 2006, Science, "Ethanol Today" avg. ethanol plant in 2001
BEACCON vs.1.1: available from www.lifecycleassociates.com; largely based on GREET
BESS: vs.2008.3.0: Scenario-1 Midwest avg. natl gas dry mill (RFA); Scenario-5 NE avg. natl gas with wet DGS
BESS has a variable co-product credit which is dependent on the emissions intensity of crop production

Most sensitive input parameters affecting ethanol yield, net energy yield, and GHG emissions

1. **crop yield, N fertilizer input requirements, and irrigation**

2. **conversion yield: liters ethanol per kg grain**

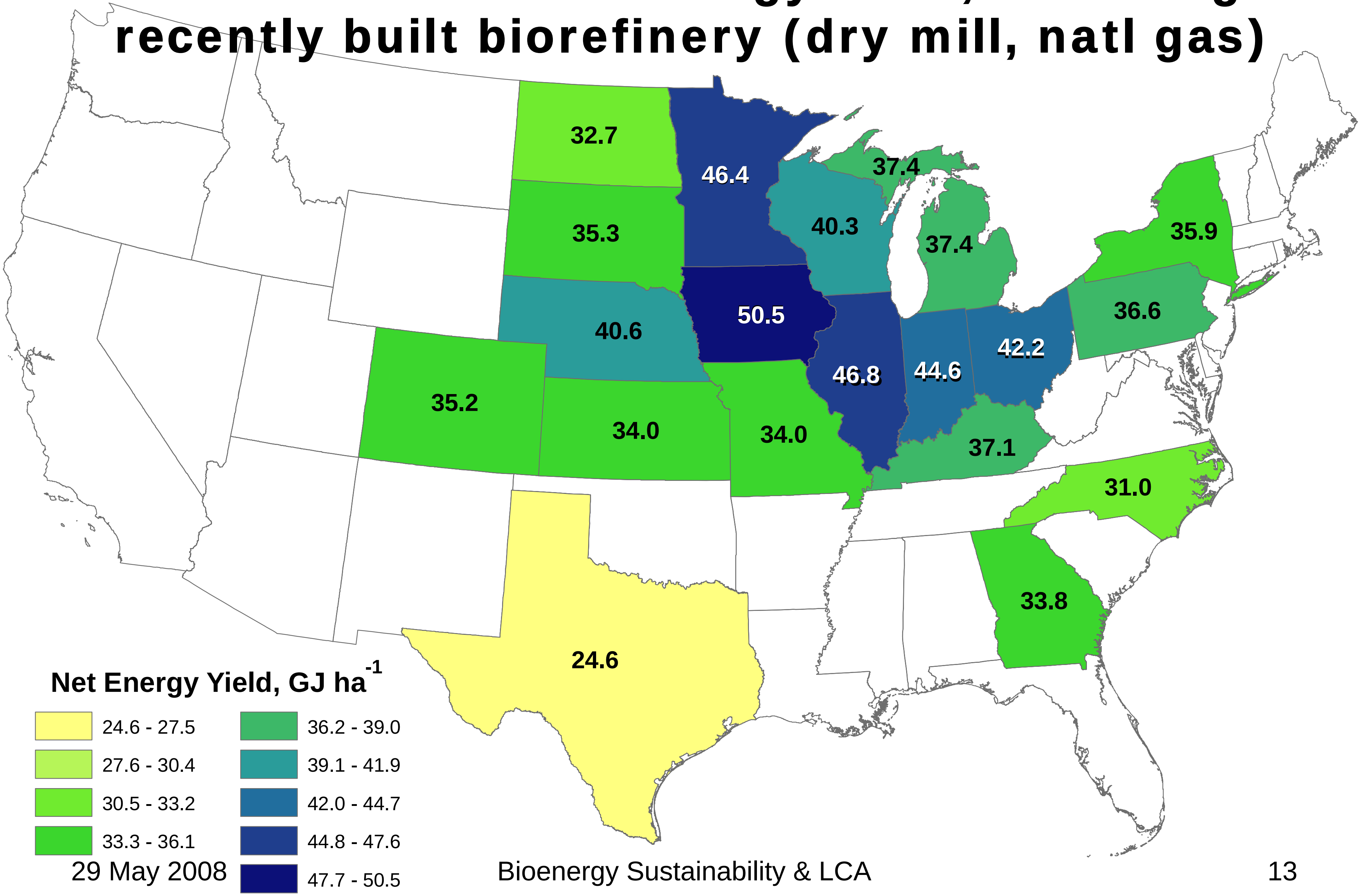
3. **Ethanol plant thermal energy inputs: MJ per liter**

Next in importance:

-wet versus drying distiller's grains

-N fertilizer rate used in crop production

BESS analysis: state-specific crop production impact on corn-ethanol Net Energy Yield, assuming a recently built biorefinery (dry mill, natl gas)



BESS vers.2008.3.0, based on state-level crop production data

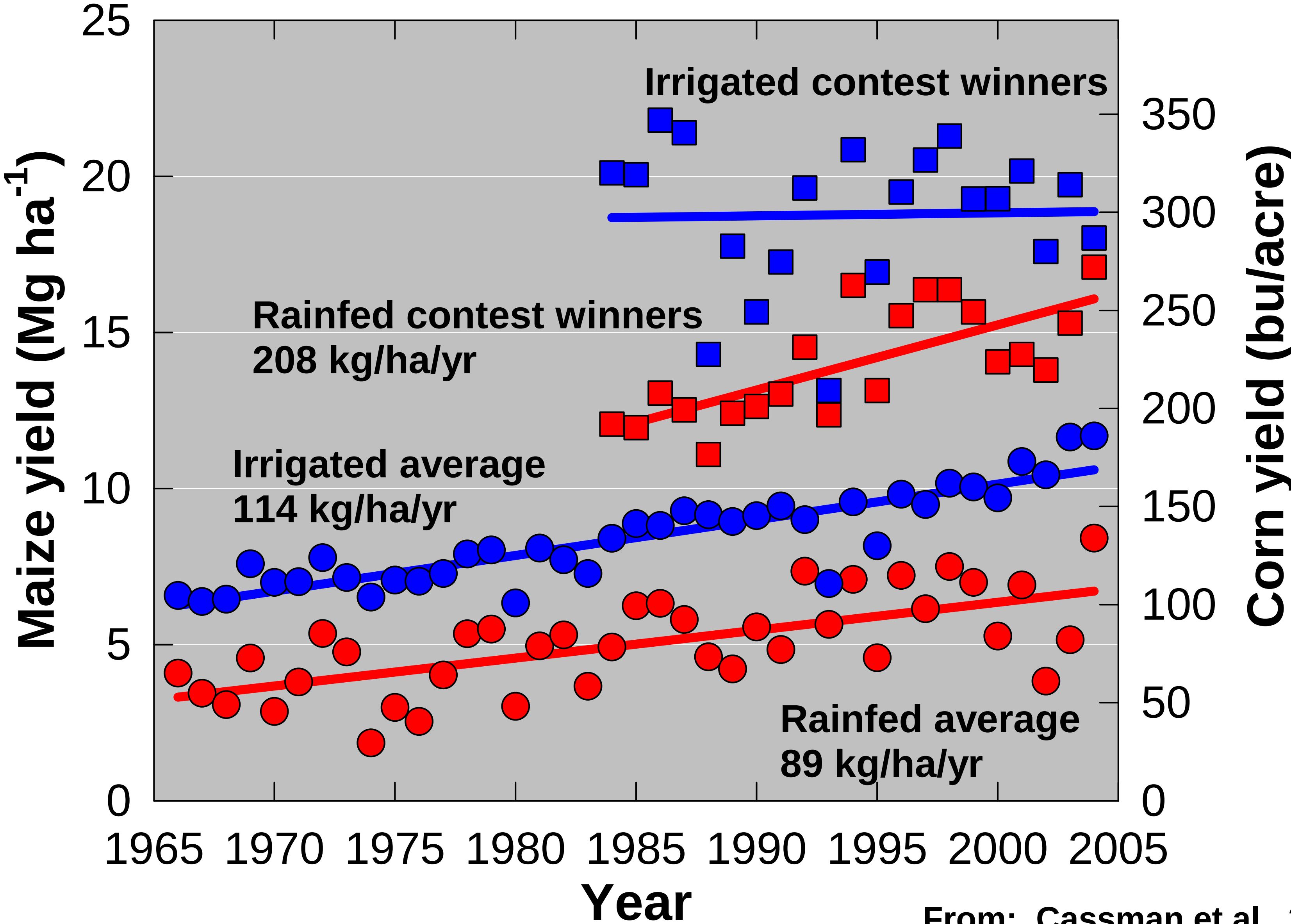
How to deal with indirect effects of land use change?

- **One value for carbon "debt" from LUC applied to all USA corn-ethanol**
- **Key issues are:**
  - **Direct-effect GHG emissions starting point (50-65% reduction as estimated by BESS, or 24% as estimated by GREET in Searchinger et al (*Science*, 2008)?**
  - **Volume of corn-ethanol production modeled by FAPRI/FASOM to estimate magnitude of land use change?**
  - **Assumptions about rate of gain in corn yields?**
- **What if there was a focused program to accelerate the rate of gain in corn yields while reducing GHG emissions per bushel produced?**
  - **A process called ecological intensification (*PNAS*, 1999)**

USA contest-winning corn yield field, 1997: 19 t/ha (ethanol yield of 7500 liters/ha)

Nebraska contest-winning and average yield trends

No increase in yield potential ceiling since the 1980s; average yields will soon approach this ceiling.



From: Cassman et al., 2003

What do policy makers and captains of industry say about corn supplies?

- **USDA Secretary Mike Johanns (11/16/06):**
  - **US farmers should be able to meet booming corn demand**
  - **We have companies telling us they are very close in their research to having more drought-resistant, more pest-resistant, more disease-resistant corn hybrids**
  - **4 to 7 million idled CRP acres are viable for corn production**
- **Robert Fraley, Chief Technology Office, Monsanto: National Renewable Energy Conf, St Louis, 10/12/06**
  - **Average corn yields will double within the next 30 years (2.3% per year exponential growth rate versus actual current linear rate equal to 1.2% of current trend-line yield)**
  - **New biotech hybrids will achieve substantial yield increases under drought and require less N fertilizer**
- **Little published in refereed journals to support these claims; most crop physiologists/agronomists who work on corn yield potential contest this prognosis**

Need for Ecological Intensification¶

- **Development of high-yield crop production systems that protect soil and environmental quality and conserve natural resources**
- **Characteristics of EI systems:**
  - **Yields that reach 85-90% of genetic yield potential**
  - **70-80% N fertilizer <u>uptake</u> efficiency**
  - **Improve soil quality (nutrient stocks, SOM)**
  - **Integrated pest management (IPM)**
  - **Contribute to net reduction in greenhouse gases**
  - **Have a large net positive energy balance**
  - **In irrigated systems: 90-95% water use efficiency**

¶Cassman, 1999. *in* Proc. Natl. Acad. Sci (USA):5952-5959

CONCLUDING REMARKS

- Corn ethanol will be first to test the newly developed LCFS assessment methods; substantial amounts of other biofuels will come 5-10 years later
- Accurate valuation of direct-effect GHG emissions from corn ethanol is the foundation of the LCFS process; these affects vary with ethanol biorefinery type and corn feedstock supply
- Different reference GHG emissions values are needed for each major class of ethanol plant and region
- The BESS model provides the most up-to-date, scientifically sound estimate of corn-ethanol GHG emissions; can BESS and GREET reach agreement?
- EPA/CARB LCFS must be based on transparent parameters and supporting science!
- Certification and compliance tools are also needed

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FREE download of BESS model: www.bess.unl.edu

- BESS model for CELLULOSIC ETHANOL from Corn residue and switchgrass, *Summer 2008*

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SOME OPTIONS ARE CLEARLY WORSE THAN OTHERS

The good versus the perfect

THANK YOU!