Use of Cropland for Biofuels Increases Greenhouse Gas Emissions Through

Land Use Change

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Most Estimated U.S. Potential Biomass No Land Use Change

DOE –" Billion Ton Supply"

Forest product residues	145
Logging residues	64
Urban wood residues	47
Agricultural residues	428
Process residues/manure	106
	790

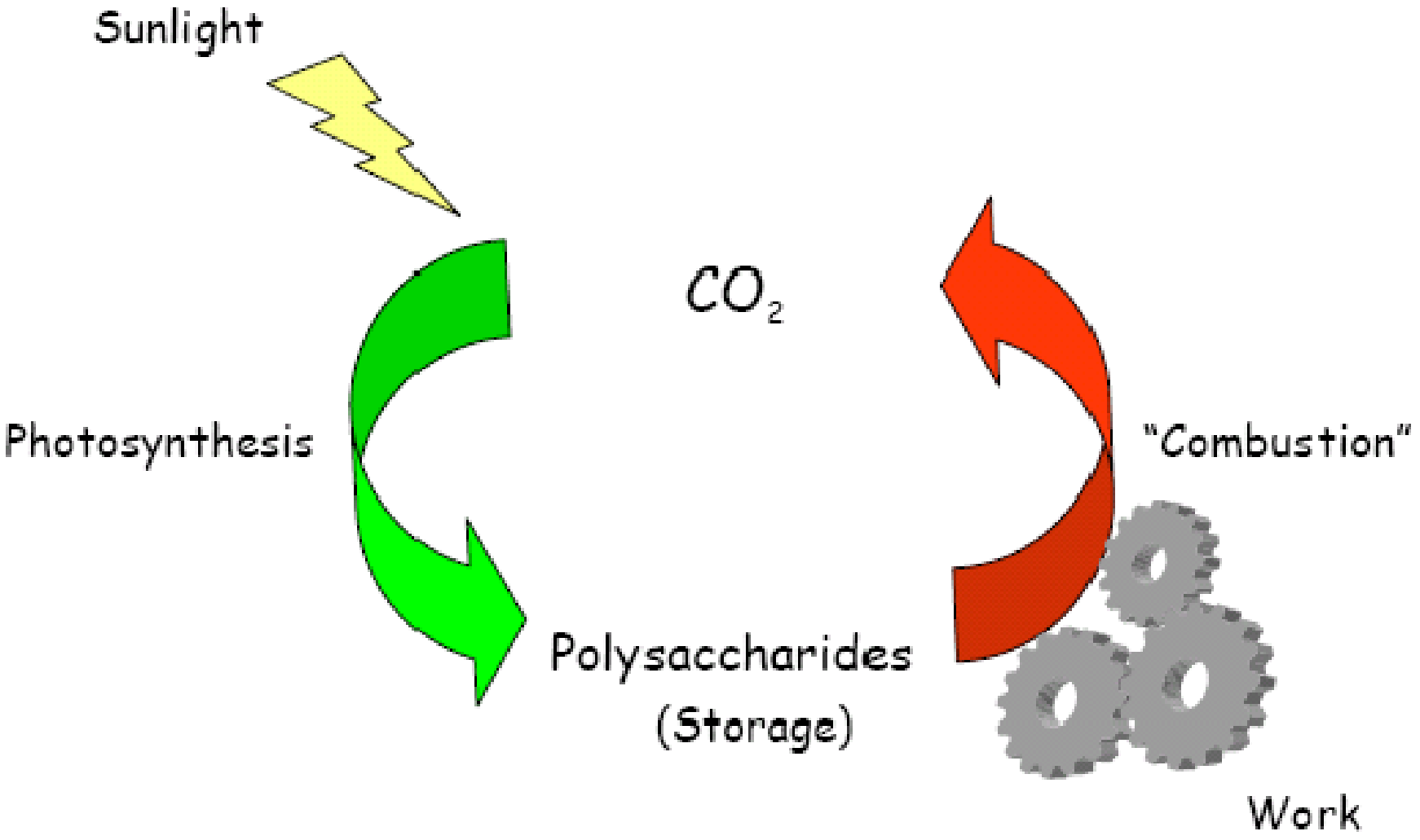
Other Sources

Municipal solid waste	100
Cover crops (summer/winter)	200
	300

- Algae
- Flue gases
- Fall harvests from CRP

- DEVELOPING COUNTRIES – MARGINAL LAND!

Combustion of biomass provides carbon neutral energy



Feedstock Credit is Critical to Findings of Greenhouse Gas Benefits

Source of Fuel*	Making Feed-stock	Refining Fuel	Vehicle Operation (Burning Fuel)	Net Land Use Effects		Total GHGs	% Change in Net GHGs vs. Gasoline
				Feedstock Uptake from Atmosphere (GREET)	Land Use Change		
Gasoline	+4	+15	+72	0	–	+92	–
Corn Ethanol (GREET)	+24	+40	+71	-62	–	+74	-20%
						+135 without feedstock credit	+47% without feedstock credit

Greenhouse gasses (CO_2) per mega joule of fuel

Why a feedstock credit?

- Land already exists
- Forests and Grassland
- Cropland produces carbon benefit in form of protein, carbohydrates, fats.

Land Use Change Emissions Mean All Foregone Storage and Ongoing Sequestration

Emission from Land Use Change

- Release of carbon stored in plants and soil when forest and grassland is plowed up directly or indirectly

Foregone ongoing sequestration

- Foregone annual, ongoing carbon sequestration on former grassland and forest that was converted or on croplands that would revert to grassland or forest absent biofuel demand


Brazil

What About Abandoned Lands in Eastern Europe or Former Soviet Union?

- Our average Latin America – 337 t/ha
- Former Soviet Union Abandoned – 328 t/ha (assuming 50% forest, 50% grassland, 10 years of abandonment)
- Compare 711 t/ha temperate evergreen forest with 823 t/ha tropic rainforest

Feedstock Credit Without Land Use Change Is One Sided Accounting of Land Use Effect

Biofuel can only justify atmospheric credit if:

(1) growing feedstock for biofuel causes a NET INCREASE in carbon removed by land overall, or

(2) the biofuel uses material that would otherwise return to the atmosphere anyway without doing work.

Land use change emissions are necessary to calculate the net land use effect

The Basic Story

- Most diverted grain replaced (even after crediting biofuel feed by-products)
- Breaking out cropland will replace most new demand
- Gains versus losses are low

Corn-based ethanol (2015)	1.8 tonnes/hectare/year gain (GHG Co2 eqv.)
Switchgrass (2015)	*8.6 tonnes/hectare/year gain*
versus	
Forest conversion	604-1146 tonnes/hectare loss + ongoing sequestration
Grassland conversion grass	75 – 305 tonnes/hectare loss (+ displaced feed)

Our weighted average 350 t/ha

GREENHOUSE GAS RESULTS

grams of greenhouse gas emissions (CO_2 equ.) per mega joule

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Corn Ethanol + Land Use Change	**+24**	**+40**	**+71**	**-62**	**+104**	**+177**	**+93%**
Biomass Ethanol (GREET)	**+10**	**+9**	**+71**	**-62**	–	**+27**	-70%
Biomass Ethanol + Land Use Change	**+10**	**+9**	**+71**	**-62**	**+111**	**+138**	**+50%**

Biodiesel, Sugarcane & Cellulosic

- Biodiesel from soybeans increases GHGs by 158% over 30 years – higher CO2 per mega joule
- Switchgrass (95 gallons/ton, 18 t/ha, 690 gallons/acre)
  - Miscanthus at 36 t/ha = ~10% reduction in GHGs
  - Miscanthus at 2500 gallons/acre = ~ 35% reduction
- Brazilian sugarcane
  - 85% reduction without land conversion (Macedo et al.)
  - 4 year payback period if conversion from grassland, and 45 years if converted from rainforest forest directly or indirectly
  - Can we avoid indirect land use change?

Other Studies

- EU Joint Research Center – If only 2.5% of rapeseed oil replaced by palm oil in peatlands, no greenhouse gas benefits
- Berkeley/Purdue Universities – corn ethanol similar to our study
- OECD – similar amount of land use change per liter of ethanol
- U. Minn & U. Wisc. Papers similar estimates from forest or grassland conversion

Key Misunderstandings

- Role of Yield
- Baseline evolves is not static
- Other causal factors, complexity of deforestation
- What if we all became vegetarian?
  - Question is not how much land is available, it is the relative value of using land one way versus another

Review of Deforestation Articles

- “agricultural expansion is, by far, the leading land use change associated with nearly all deforestation cases”
- “economic factors could, thus, be labelled as the most important and robust underlying forces of tropical deforestation.”

» Geist & Lambin (2001) (2002)

Some Key Undercounting Factors

- No wetlands outside of SE Asia
- No conversion for pasture & diverted forage not replaced
- Nitrous oxide emissions factors
- Feedback effects, e.g., drying out of rain forest

Unanswerable Uncertainty – How Will Government's Respond to Higher Prices & Hunger?

Blairo Maggi, Governor of Mato Grosso and Soybean King, April 25, 2008: "With the worsening of the global food crisis, the time is coming when it will be inevitable to discuss whether we preserve the environment or produce more food. There is no way to produce more food without occupying more land and taking down more trees. In this moment of crisis, the world needs to understand that the country has space to raise its production."

Indirect Effects Mean Typical Certification Approach Does Not Work

When you divert cropland to biofuels

1. People consume less food

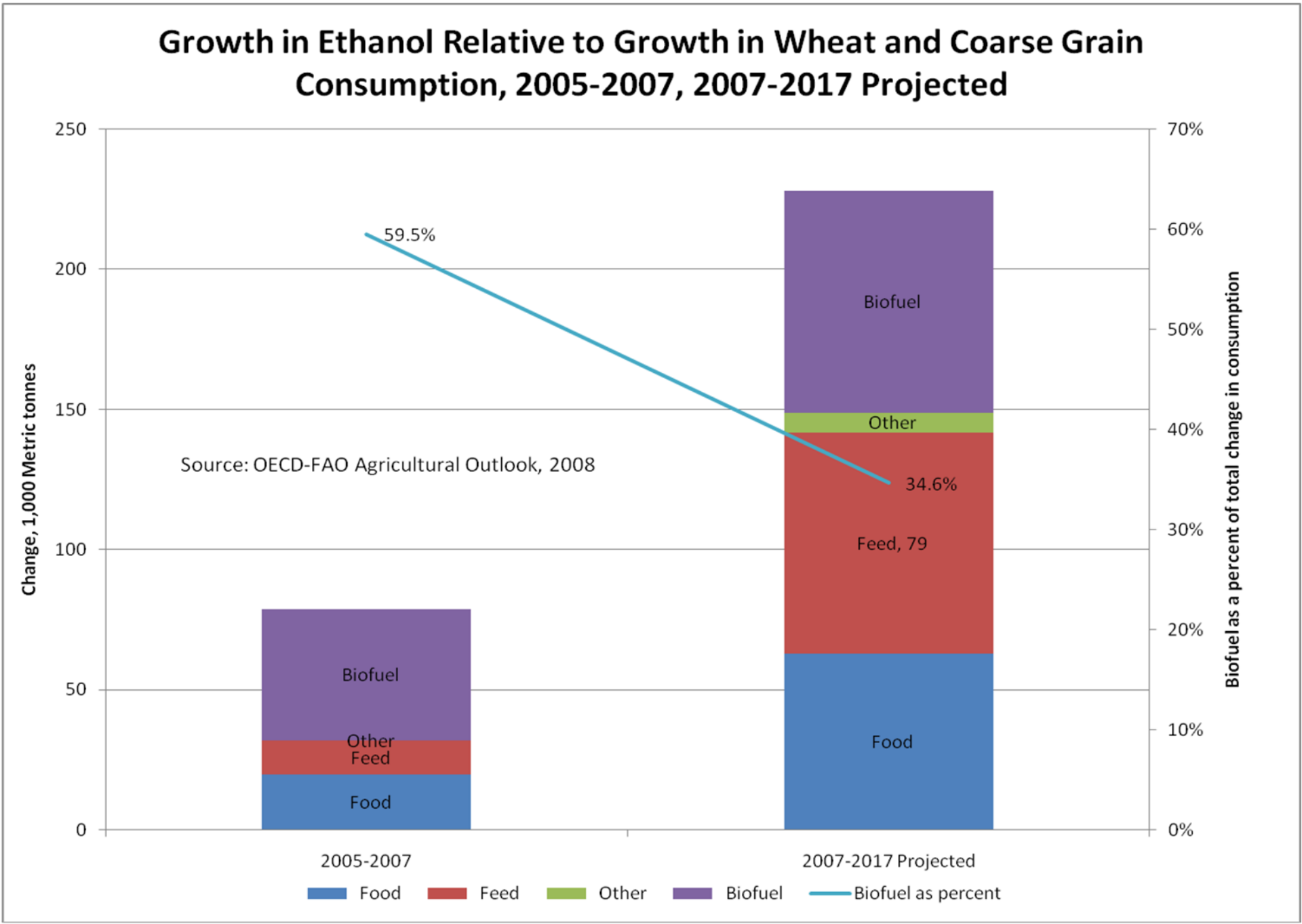
2. Farmers plow up more land

3. Farmers additionally boost yields


The new situation: Surge in prices
New trend?
Corn
Wheat
Rice
Oil (right scale)
US$/ton
US$/barrel
800
600
400
200
0
100
75
50
25
0
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Source: Data from FAO 2008 and IMF 2008.

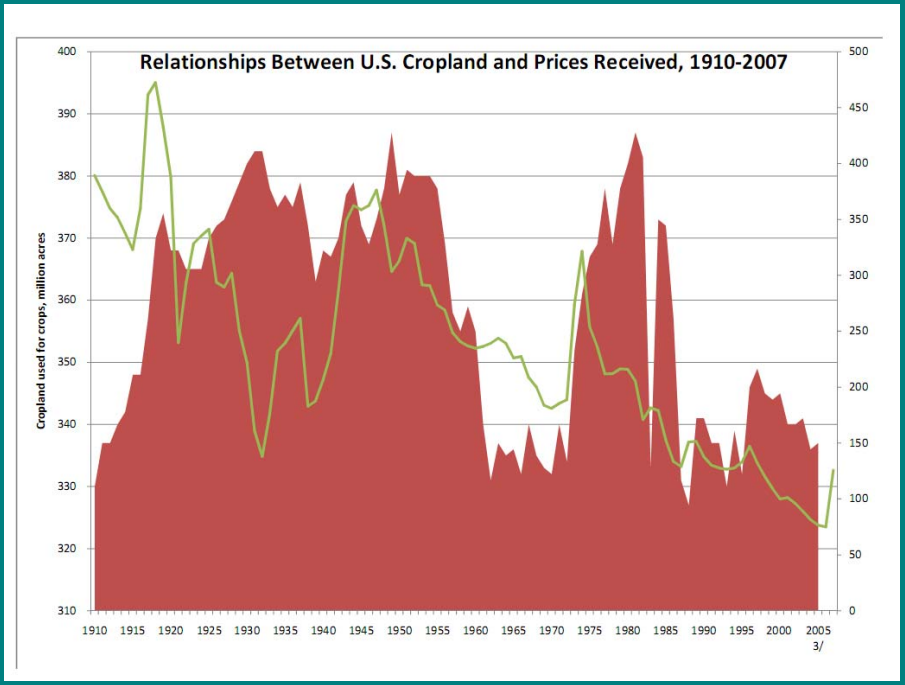
Biofuels & Food Prices

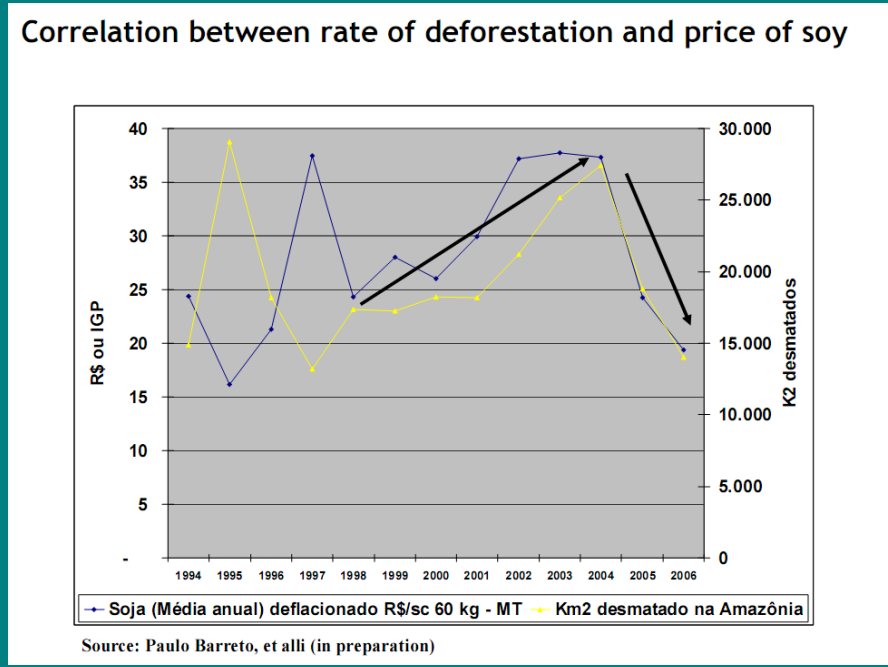
- FAO – biofuels “one of the leading factors” in world price increases
- International Food Policy Research Institute – 30% of price rise from 2000-2007 average
- World Bank Study – 65% of price rise
- IMF – biofuels substantial factor in price rises


Growth in Ethanol Relative to Growth in Wheat and Coarse Grain Consumption, 2005-2007, 2007-2017 Projected
Change, 1,000 Metric tonnes
Biofuel as a percent of total change in consumption
250
200
150
100
50
0
70%
60%
50%
40%
30%
20%
10%
0%
59.5%
34.6%
Source: OECD-FAO Agricultural Outlook, 2008
Biofuel
Other
Feed
Food
Biofuel
Other
Feed, 79
Food
2005-2007
2007-2017 Projected
Food
Feed
Other
Biofuel
Biofuel as percent

-Biofuels now 5.5% of world cereals & 8% of world vegetable oil

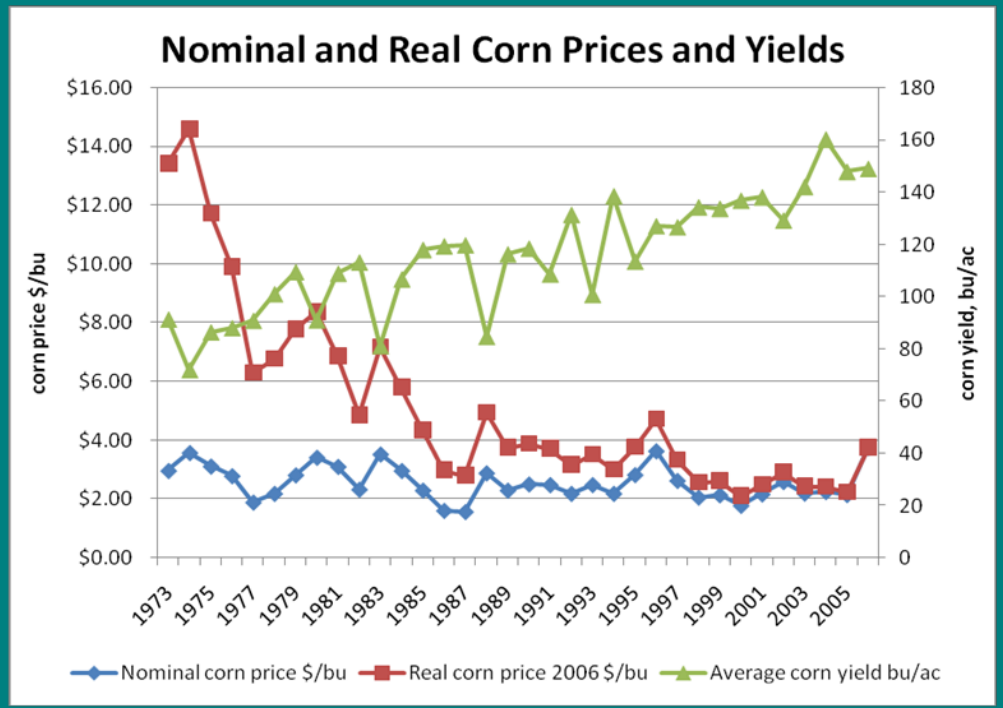
16% of world malnourished
1/3 of children in developing world stunted
30 million babies born impaired due to lack of natal nutrition
5 million children die annually from causes related to lack of nutrition





Strong relationship between price and amount of cropland

Weak studied relationship between price and yields



Implied Yield Growth by 2020 Scenario 10.2% Transport Fuel(Etech 4)

Crop	Biofuels, adjusted for by products	Non Biofuel food demand	Biofuel and Non Biofuel	1996-2006 Trend
Cereals (corn,wheat	0.8%	1.8%	2.6%	1.3%
Oilseeds (soy, rape)	0.9%	2.2%	3.2%	1.5%
Sugar (cane)	5.0%	0.6%	5.5%	0.8%
Palm	3.0%	3.9%	6.9%	1.9%

Arguments for/against large price-yield response

- Longer term elasticities larger
- Change in who farms
- Technological improvement
- Developing world has capacity for input substitution

- 15 billion gallons ethanol requires 3x increase in yield rate
- Use of more marginal land
- Most world ag already uses high inputs
- 2/3 world research is public
- Rate of yield response declines as prices rise
- Tightening food means largge price signal even without biofuels
- Recent yield increases
  - Palm oil SE Asia – flat since 1985
  - Sugarcrops - .8

GHGs from Nitrous Oxide For Yield Gains

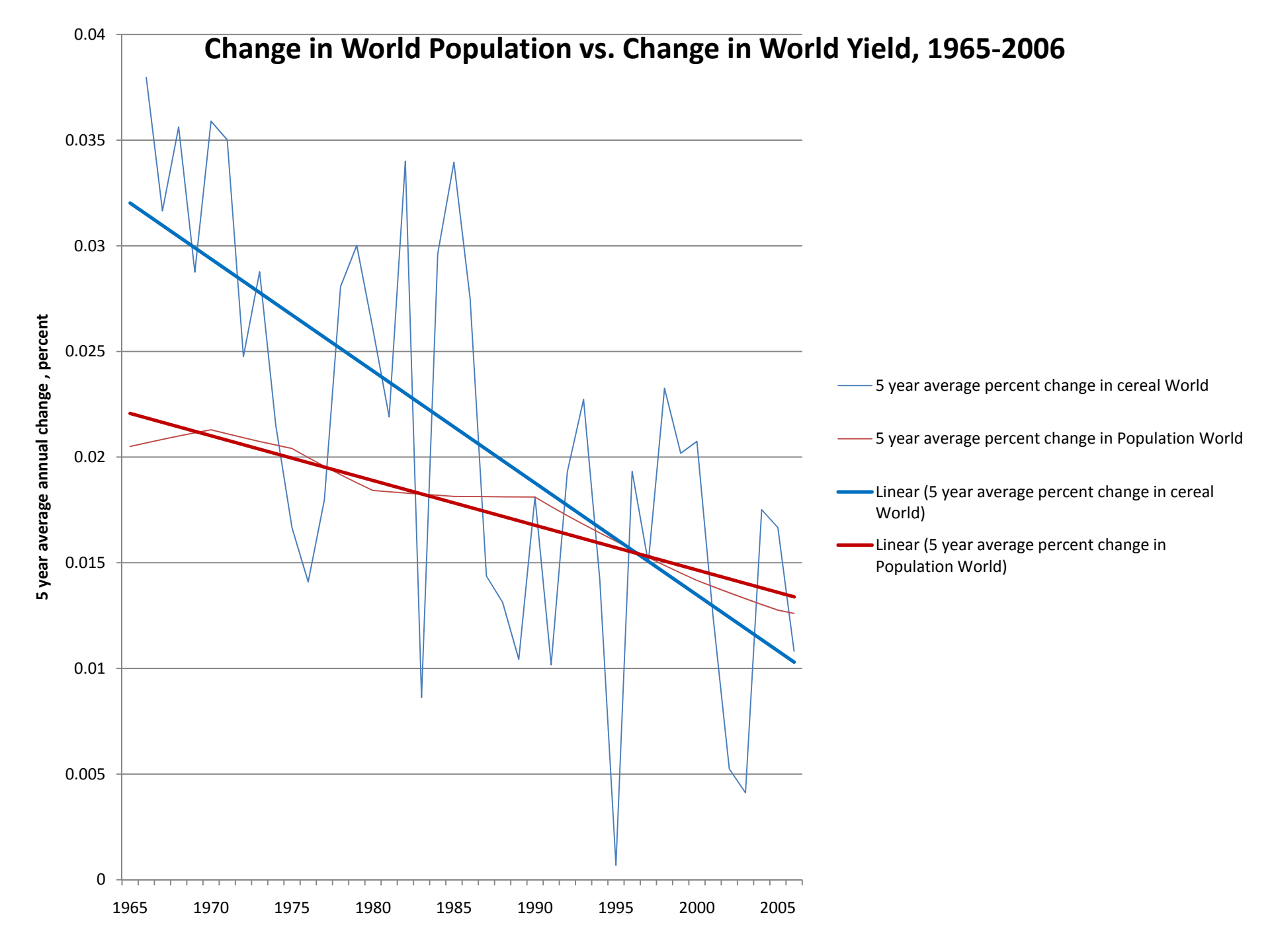
Through Fertilizer (assuming 7 extra additional lbs of fertilizer/bushel of corn)

N_2O Formation Rate	Greenhouse gases (CO_2 eq.)/km
2%	401
3%	603
4%	803
5%	1003
6%	1204

Compare 316 g/km from land use

Relying on Price/Induced Yields in Policy Context

- Risky & likelihood of bad result robust
- Relies on world farmers to provide GHG benefits – not biofuels
- Big price increases for 3 billion poor
- Big environmental effects: freshwater crisis; global rise in toxic algal blooms, polluted bays
- Capacity to boost yields needed to feed people


Change in World Population vs. Change in World Yield, 1965-2006
5 year average annual change , percent
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1965
1970
1975
1980
1985
1990
1995
2000
2005
5 year average percent change in cereal World
5 year average percent change in Population World
Linear (5 year average percent change in cereal World)
Linear (5 year average percent change in Population World)