Use of Cropland for Biofuels Increases Greenhouse Gas Emissions Through Land Use Change

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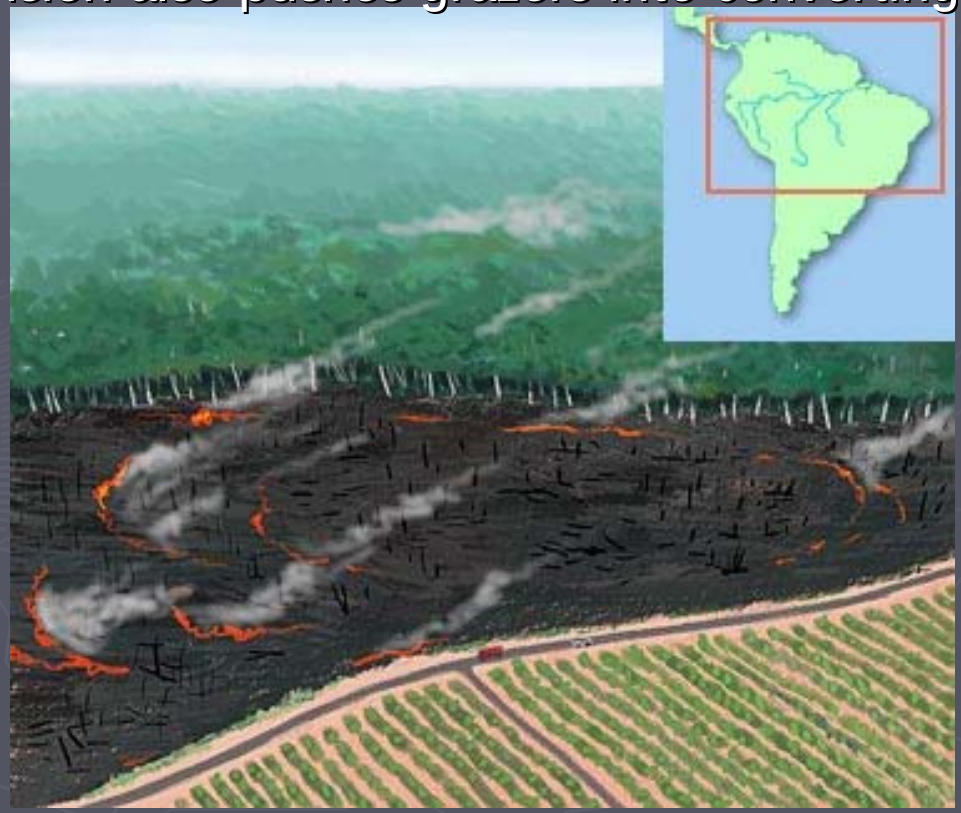
Land Conversion Means All Foregone Storage and Ongoing Sequestration

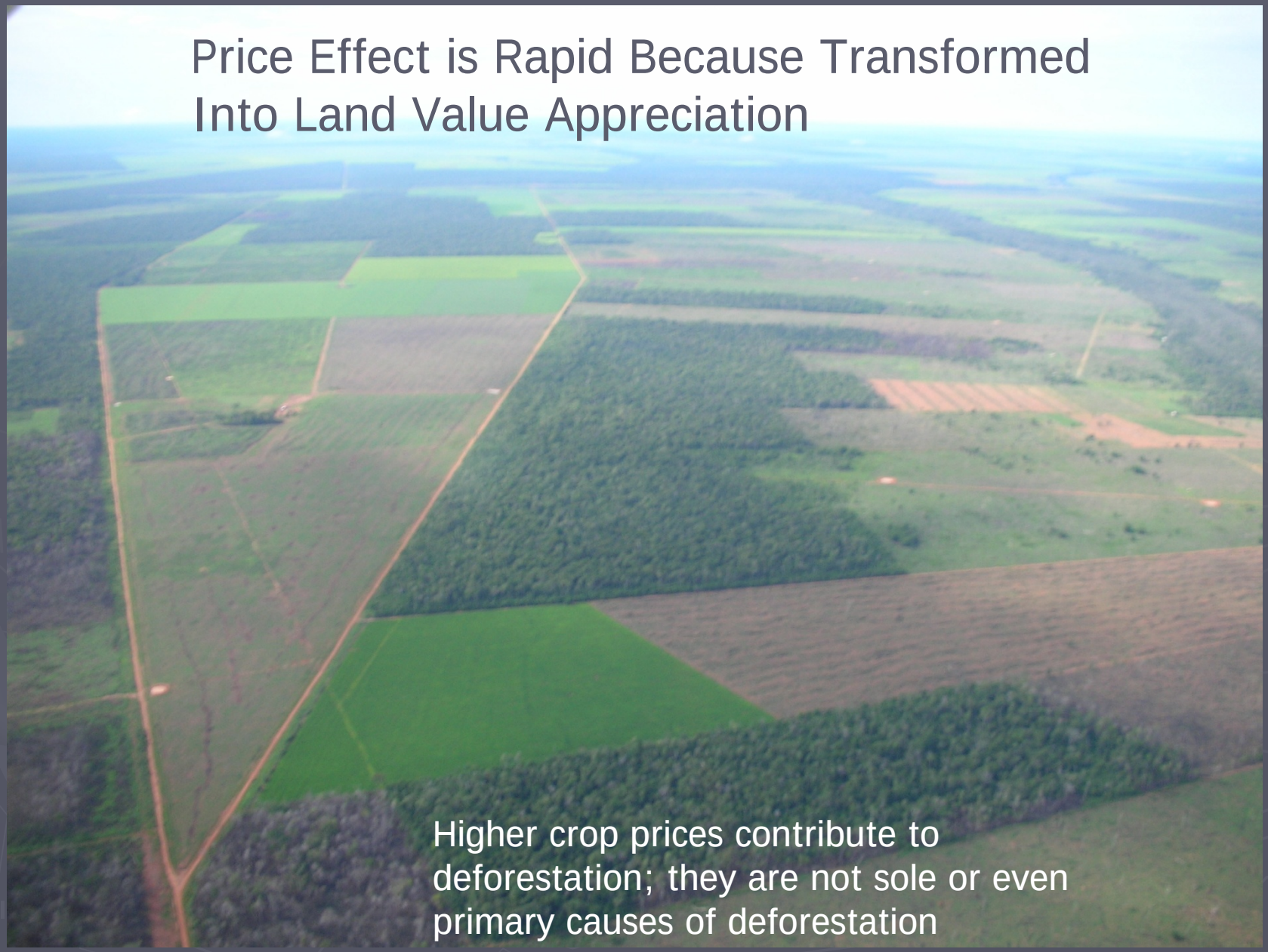
- Emission from Land Use Change
  - Release of carbon stored in plants and soil when forest and grassland is plowed up directly or indirectly
- Foregone ongoing sequestration
  - Foregone annual, ongoing carbon sequestration on former grassland and forest that was converted or on croplands that would revert to grassland or forest absent biofuel demand

Indirect Effect Occurs Through Price

- Morton et al, Cropland Expansion Changes Deforestation Dynamics in the southern Brazilian Amazon, PNAS 103(39):14637-41 – showing rate of deforestation increases with price
- 30 billion gallons of corn ethanol = 2004 U.S. corn production
- Crop expansion also pushes grazers into converting forest



Price Effect is Rapid Because Transformed Into Land Value Appreciation



Higher crop prices contribute to deforestation; they are not sole or even primary causes of deforestation

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
  - Have stored carbon for decades and may continue to sequester carbon
- Cropland produces carbon benefit in form of protein, carbohydrates, fats.
  - If we use cropland for fuel, we have to find our carbon elsewhere, displacing carbon storage

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 atmospheric credit or debt

Using Cropland to Produce Biofuels Will Cause Large Increases in Greenhouse Gasses from Land Use Change

- Most diverted grain will be replaced (even after crediting biofuel feed by-products)
- Breaking out cropland is cost-effective way of meeting new demand
- Losses on any forest or grassland converted to cropland are high compared to annual gains per hectare of biofuel:

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

Our Analysis for Corn Ethanol

- Integrates 3 models
  - GREET
  - CARD Agricultural Model
  - Houghton land use change for 1990s

Conceptually

- DDG's offset diverted corn –1/3 of feed comes back
- Higher price lowers demand but modestly
- Some grain made up by higher yields – CARD assumes no net effect
  - Rising yields from increased investment offset by use of more marginal land and less rotation
- Significantly more acres abroad required to offset diverted domestic corn acres because of lower yields

Effects of 14.8 Billion Gallon Increase in 2015/16

- 32 million acre diversion of corn acres to ethanol
- Large rise in long-term grain prices (Corn from $3.16/bushel to $4.43/bushel, soybeans from $6.56 to $8.07, wheat $4.29 to $5.27)
- Huge Export Declines
  - 63% corn, 33% soybeans; 53% wheat; 21% pork; 15% chickens

RESULTS – LAND CHANGE EFFECTS

12.8 million hectares of corn diverted

10.8 million hectare increase in cropland worldwide

2.8 in Brazil, 2.2 in U.S.; 2.3 in India and China

Mix of forest, savannah and grassland

GREENHOUSE GAS RESULTS

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

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Corn Ethanol (GREET)	**+24**	**+40**	**+71**	**-62**	–	**+74**	-20%
						+135 without feedstock credit	**+47%** without feedstock credit
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%**

Results

- Corn ethanol nearly doubles emissions from driving over 30 years
- Corn ethanol pays back carbon debt after 167 years

Sensitivity

- If 20% of diverted grain replaced by increase in yields – 133 year payback
- If ethanol emissions savings, absent land conversion, double -- 83 year payback
- If per acre land emissions from conversion were half of our estimate – 83 year payback
- If all true – 34 year payback

Possible Overcounts

- Difference in production emissions abroad versus U.S.
- Reduction in enteric methane due to reductions in livestock
- Grazing land carbon
- Forest harvest and displacement
- Undercount of demand-induced yield growth

Some Key Undercounting Factors

- No wetlands outside of SE Asia
- Diverted forage not replaced
- Nitrous oxide emissions factors
- Local cooling
- Feedback effects, e.g., drying out of rain forest
  - Inherent uncertainty, response of governments to high crop prices

Key Misunderstandings

- Role of Yield
- Other factors that cause deforestation

Criticisms

- Misrepresentations of study
  - Size of increase - similar emissions per Mega Joule at lower levels of ethanol
  - Yields – we assumed rising yields in each country
  - Pristine lands – we calculated conversion in broad range of forests and grasslands, many far from pristine
- Oil land use - small
- U.S. ethanol is influencing exports
- Factors that would improve the baseline do not by themselves reduce the increment land use effects of biofuels
  - Improved forest protection

Biodiesel, Biomass & Sugarcane

- Separate analysis, biodiesel from soybeans increases GHGs by 158% over 30 years
- Biomass grown on soybean fields
  - 70% reduction without land conversion (GREET)
  - 50% increase in emissions with with land conversion
- 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
  - But it's worth exploring solutions

What about surplus cropland?

- Truly surplus crops would regain forest or grass
  - What we think of as surplus represents modest excess during years of low prices, but prices fluctuate
  - There is no surplus, productive land from carbon standpoint
- Regional and international cropland is shifting and price accelerates Latin American expansion
- Growing worldwide demand anyway for richer Asia and 9-10 billion people

EU Directive?

Indirect effects the key, indirect effects are the key, indirect effects . . . .

Proposed EU Rule Against Direct Conversion

- Easy to evade – two tanks
- Not relevant to how commodity markets work

Impacts on Food Consumptoin

- Roughly 10% of diverted feedgrains for lviestock and 6% of diverted feedgrains for drairy not replaced because of reduced meat and dairy consumption
  - Bigger biofuel mandates, bigger effects
  - Higher volatility and price spikes

What about Land Use Planning or Would Rules Against Land Conversion Eliminate Problem?

- Have to be very strong and universal
- How do you distinguish agricultural expansion for food from agricultural expansion for fuel
- Would constrain the cheapest sources of new supply. Grain and meat prices would rise dramatically for developing country poor
  - Much of greenhouse gas "benefit" would come from changed diets of poor

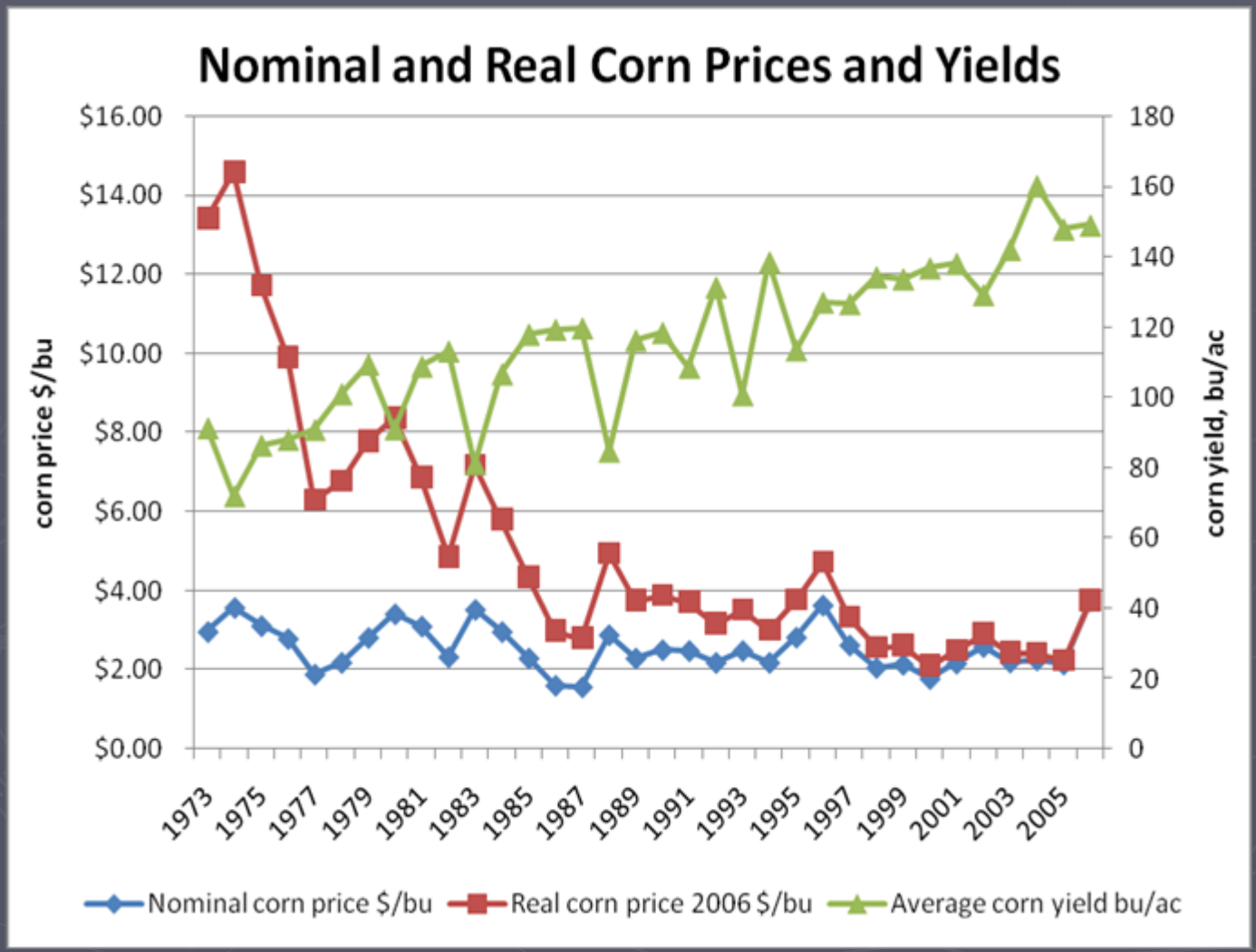
Problems with One Criterion Approach – Biodversity, Water Effects

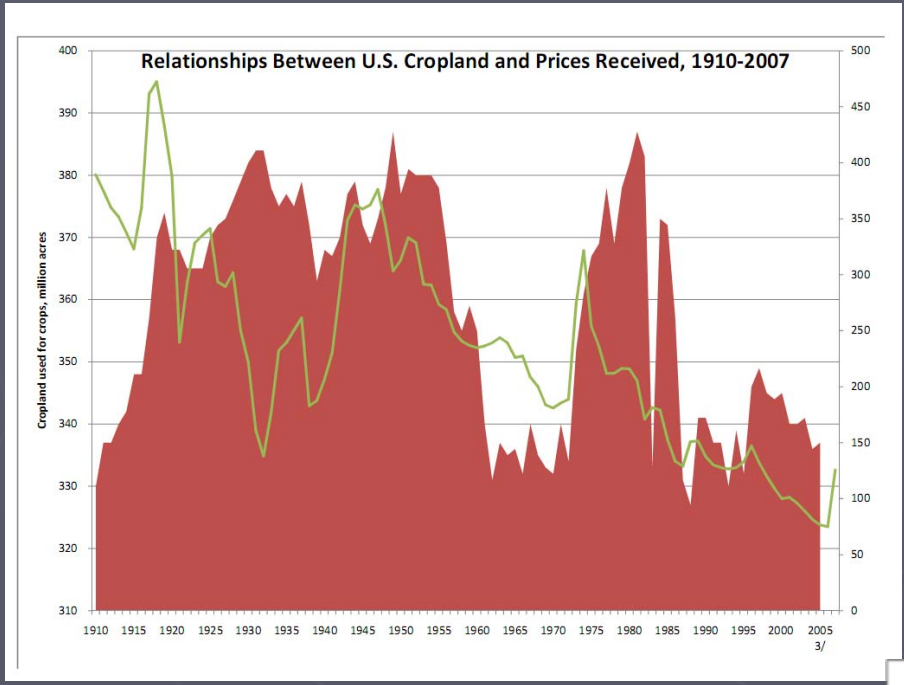
The cerrado – 10,000 plant species, 44% found nowhere else – 800 species of birds

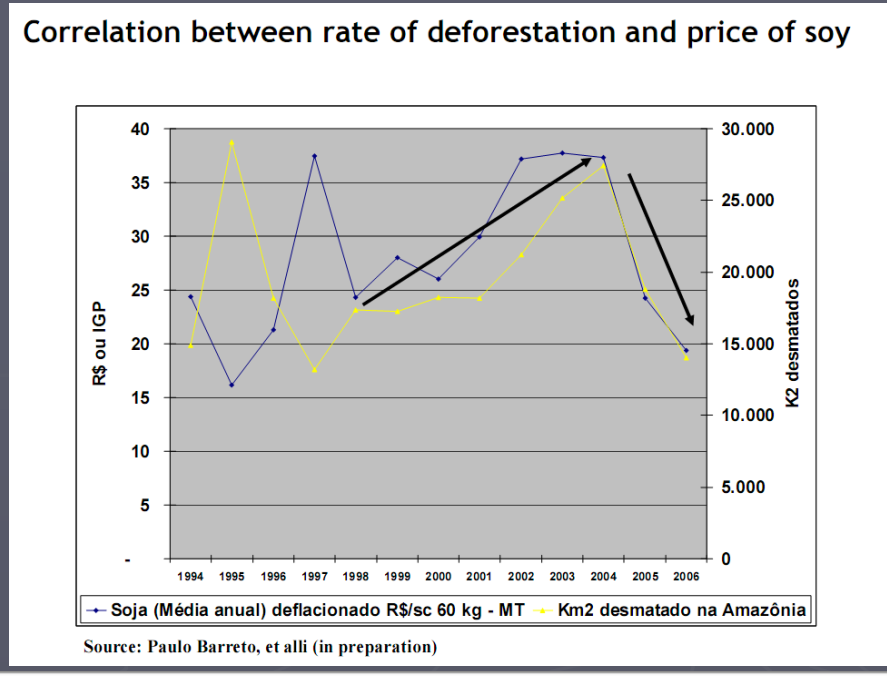
Can Demand-Driven Yield Gains Dramatically Reduce Land Use Change?

- Past experience does not show it
- Rising demand kept cropland increasing Without rising demand, world cropland would have decreased 80% in developing world, 50% in U.S.
- We assume, in effect, demand induces higher yields to supply 25% of replacement grain

Yields have risen despite declining prices.

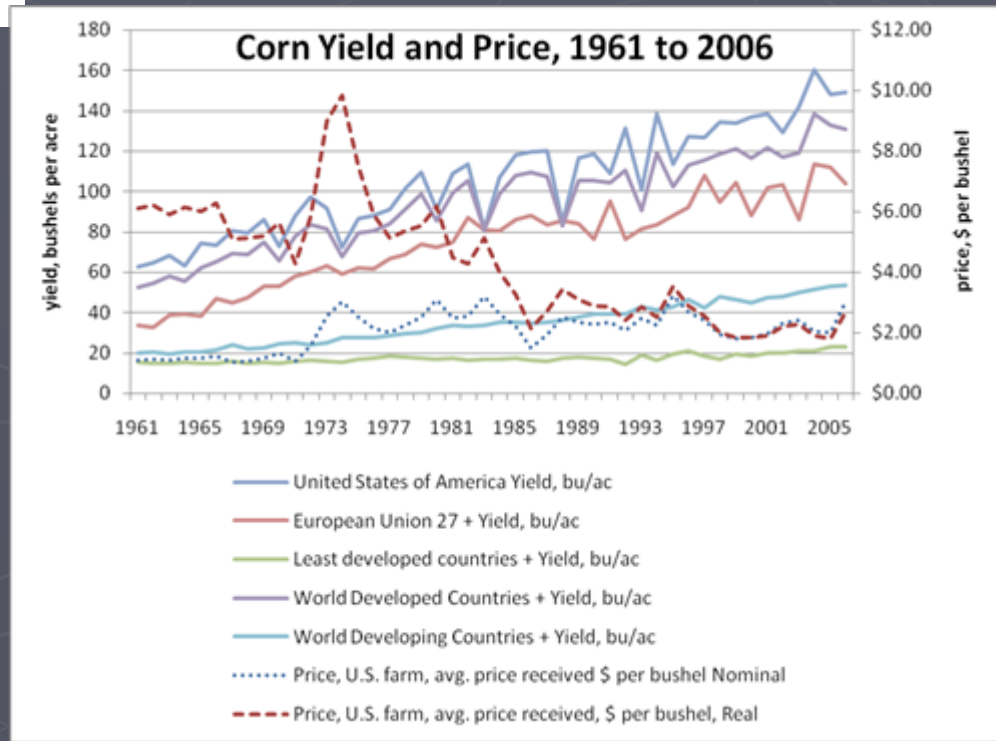






Strong relationship between price and amount of cropland

Weak studied relationship between price and yields



Fulginiti and Perrin Studies of Developing Countries

- Misinterpreted: past prices helped to explain increases in total factor productivity not yield
- Past prices did not explain inputs of fertilizer and machinery, the primary determinant of yields
- Yields increased dramatically even though productivity declined

Policy Context

- Our result is robust – assumes roughly 25% of grain replaced by price-induced yields. If 63% of grain so replaced, corn ethanol still large net negative
- Don't rely on world farmers to boost carbon uptake; require biofuel production to do so
- Relying on price-induced yields means big price increases for 3 billion of the world's poor
- Improving yields also has large environmental effects: UN, freshwater crisis; global rise in eutrophication
- Capacity to raise yields not unlimited – much bigger yield increases already needed to feed 9.5 to 10 billion and reduce deforestation

Where Should We Focus

- Biofuels from waste products - biggest cheapest source
- Use of “marginal,” unproductive lands (carefully)
- Winter cover crops
- Algae
- Fall harvests from reserve lands

Recommendations

- Do not increase mandate
- Provide incentives for biofuels that do not use productive land
  - Blanket rule for waste (as defined)
  - Case by case or category approval for uses of marginal land
- Explore a deal with Brazil
  - Buy ethanol if Brazil protect forests and boosts pasture yields

Larger Context

- Capacity to raise yields not unlimited
- Land use change 20% of CO2 Emissions
- Need land use change while feeding to dramatically boost yields already reduce billions more people eating more meat