What Will it Take to Make Corn Ethanol Meet Greenhouse Gas Performance Standards?

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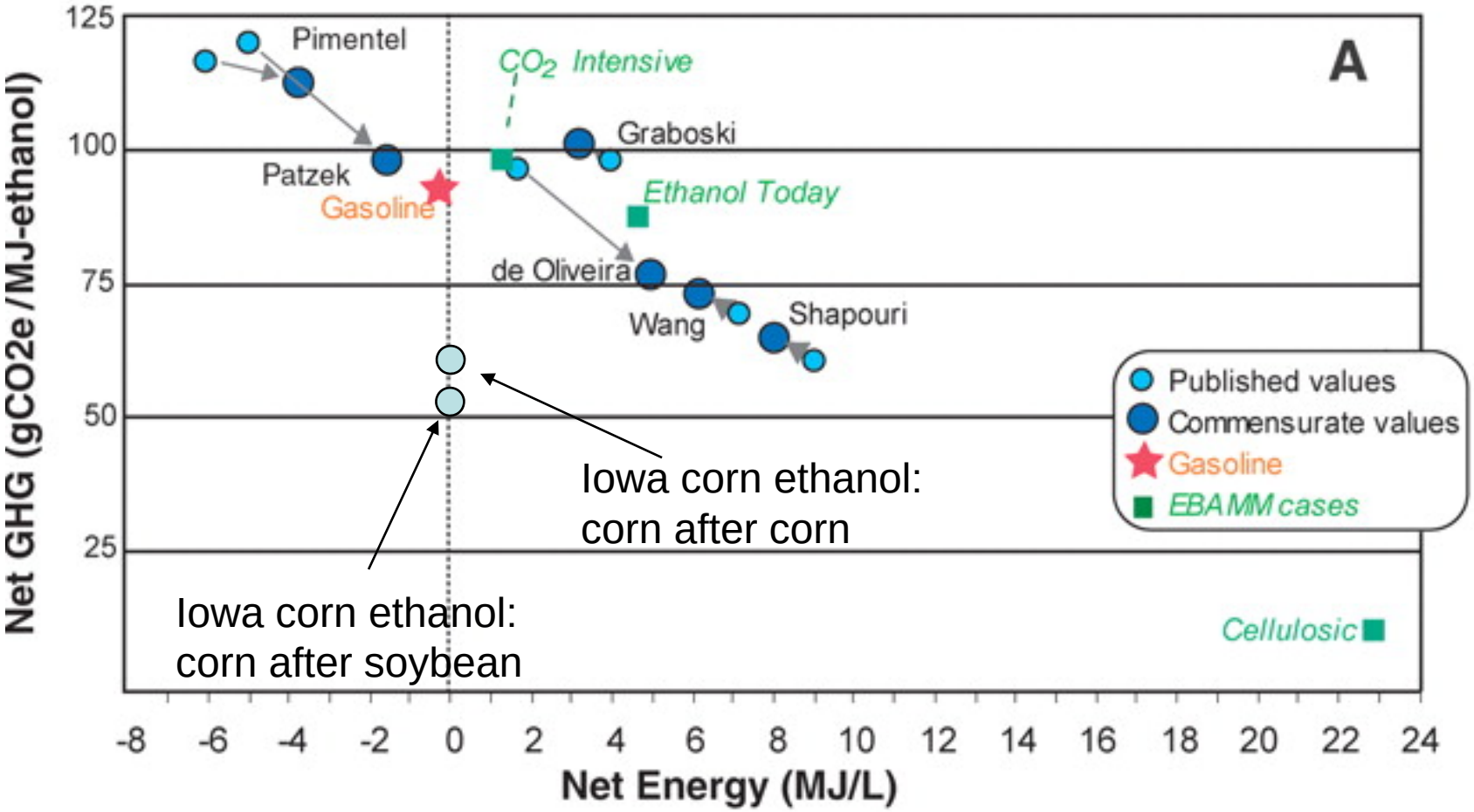
Motivation

- Do biofuels that use feedstock grown on crop land increase or decrease greenhouse gas emissions?

- Life cycle analysis of biofuels seems to suggest that renewability of feedstocks leads to reduction in greenhouse gas emissions



A. E. Farrell et al., Science 311, 506 -508 (2006)

Large Scale Actions can Have Unintended Effects

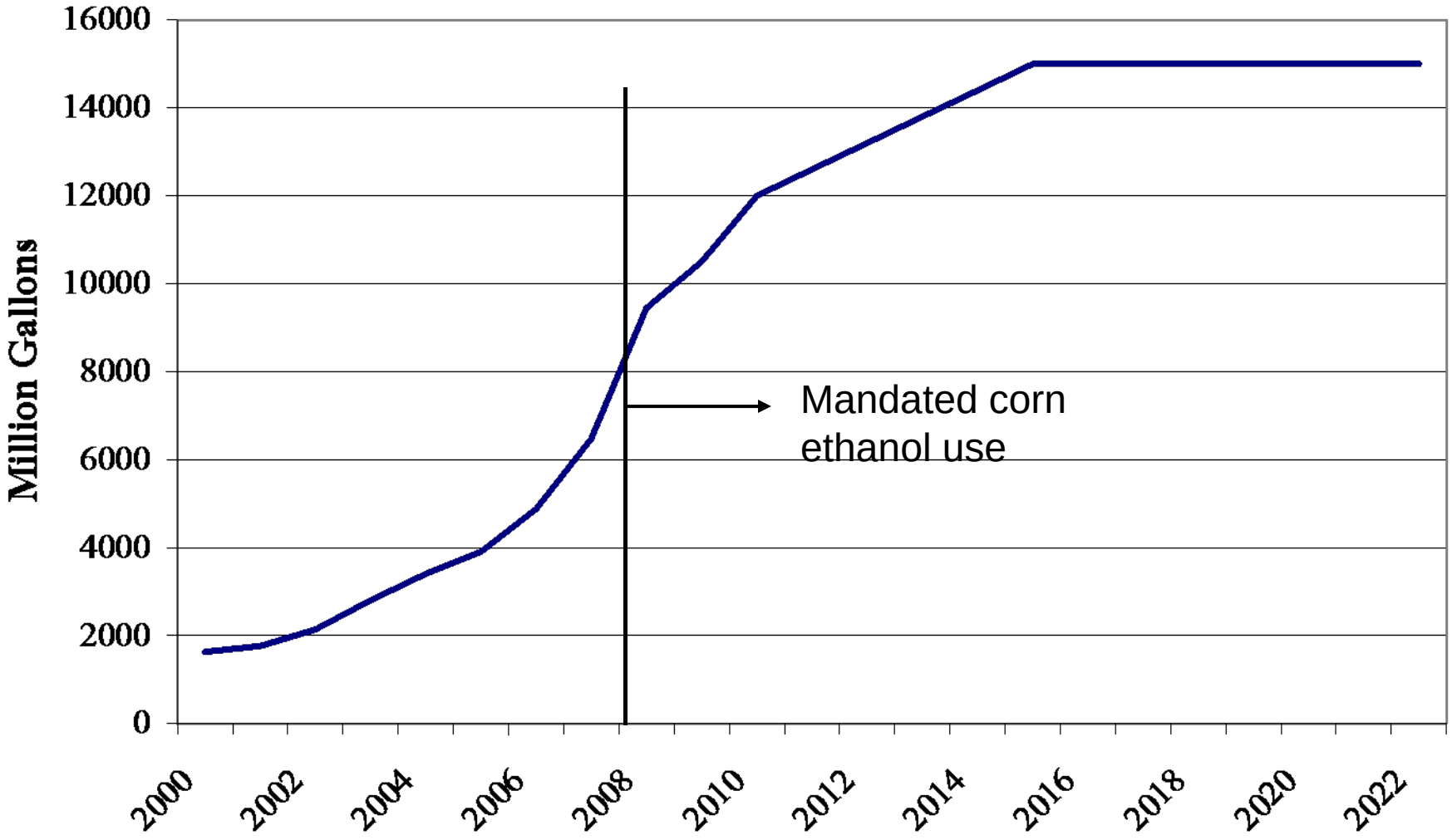
- Redwoods:
  - Berck and Bentley estimate that the 1978 governmental takings of old-growth redwood for inclusion in the Redwood National Park increased the price of redwood lumber by 26%.
  - Higher prices typically lead to greater production
  - Cutting rate increased on non-targeted areas
  - Should the net benefit of the park expansion be reduced by the loss of forest outside the park?

CRP

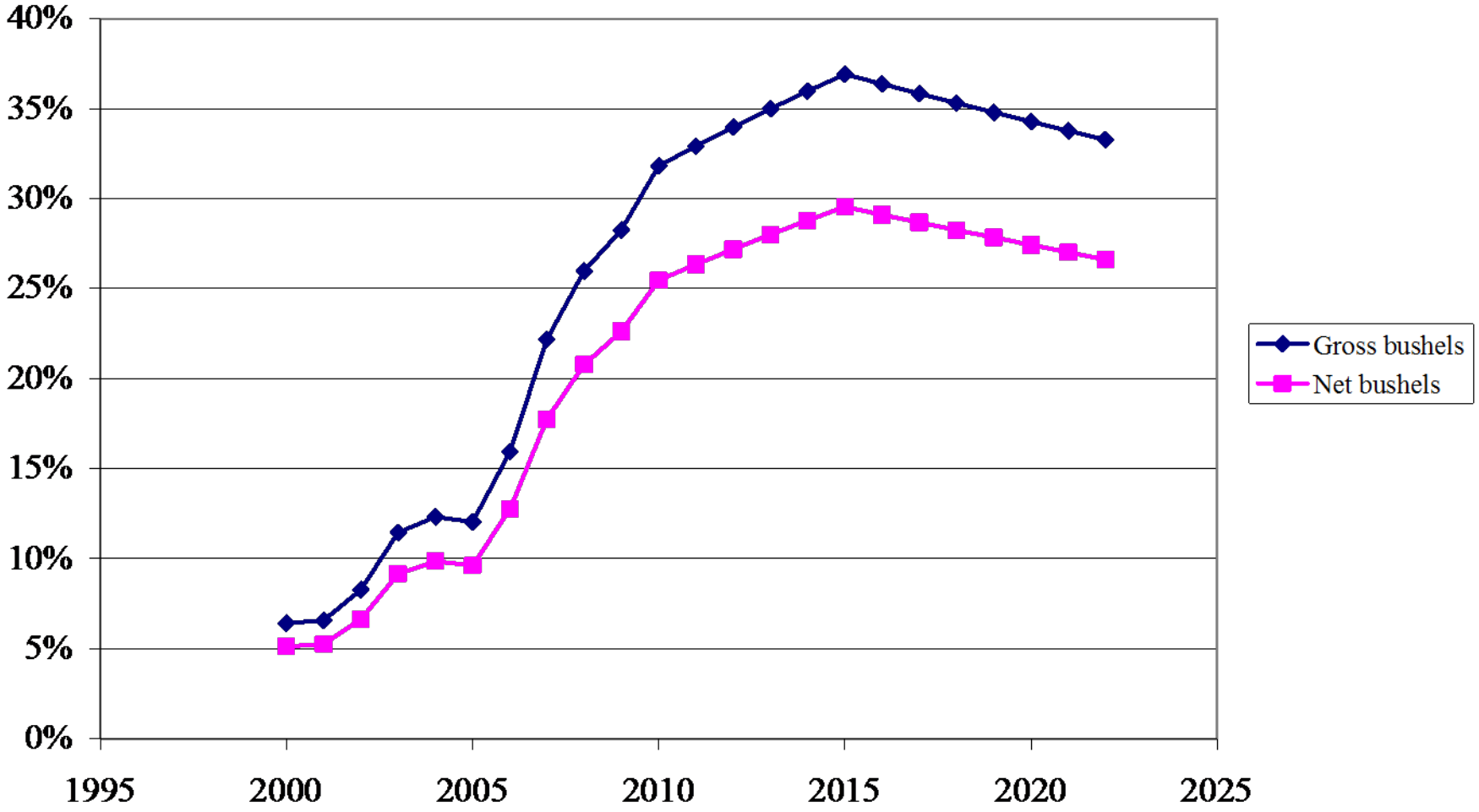
- U.S. took 35 million acres of cropland out of production for 10 years
- But ag markets recovered through the 1990s
- Wu estimates that 7 million acres of land came into production because of the price effects of removing 35 million acres
- Should the environmental benefits of CRP be adjusted downward?

How Much Corn Diverted from Feed?

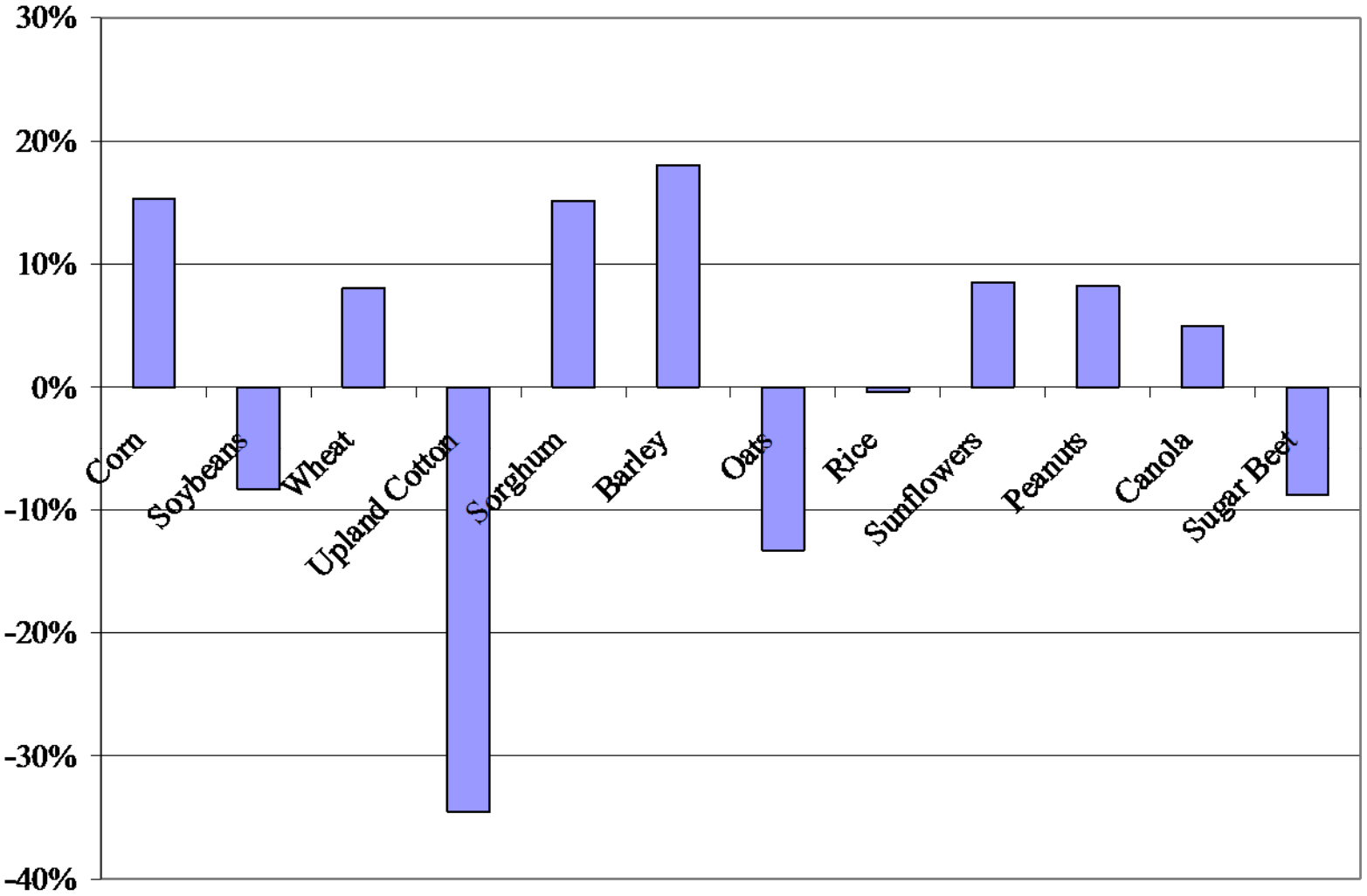
U.S. Ethanol Production With New EISA Mandates



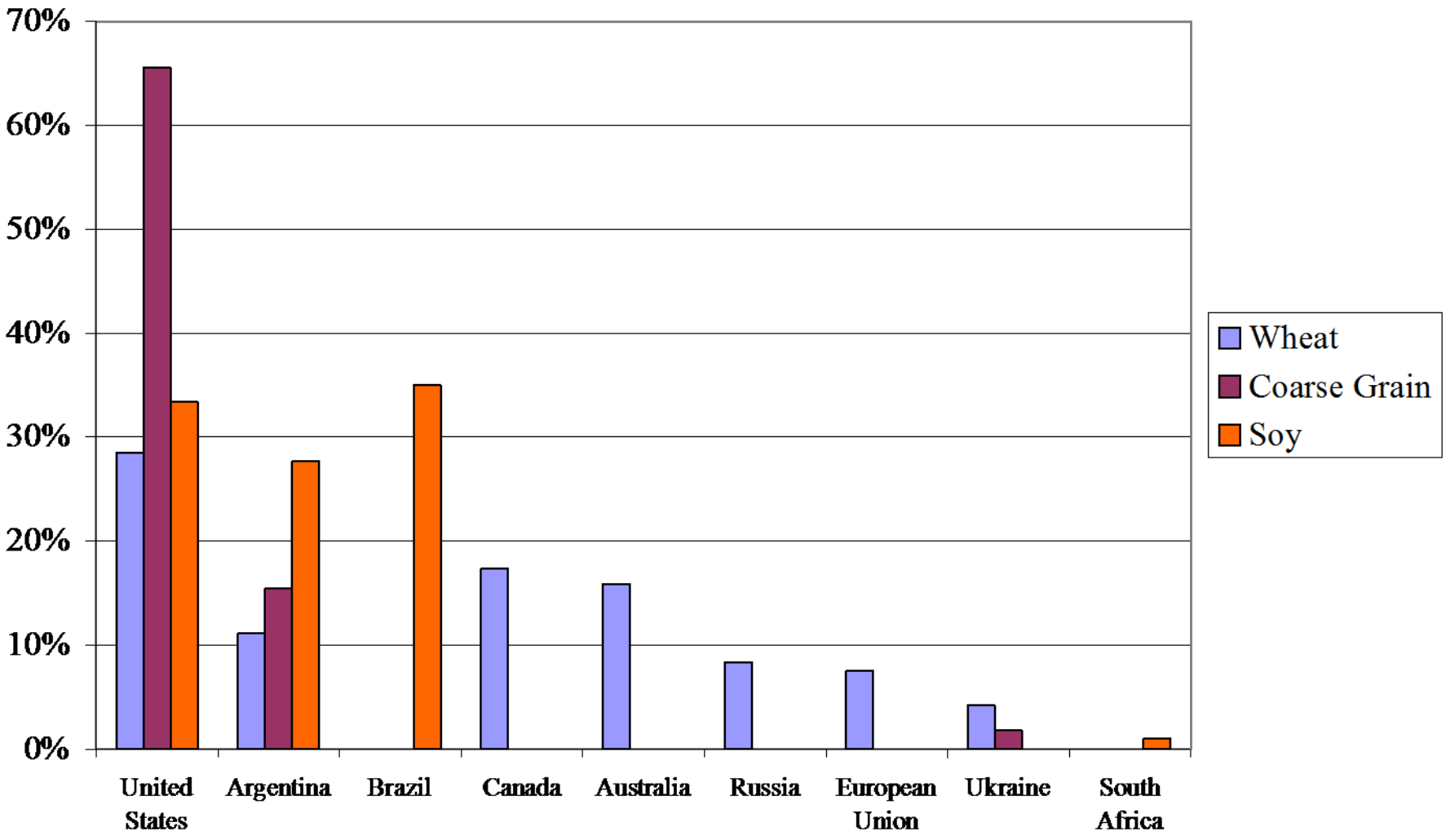
Corn Utilized for Ethanol
(Assumes 1.5% increase in annual production from 2007 base)



Percent Change in Average Planted Acreage in 2007 and 2008 Relative to 2006

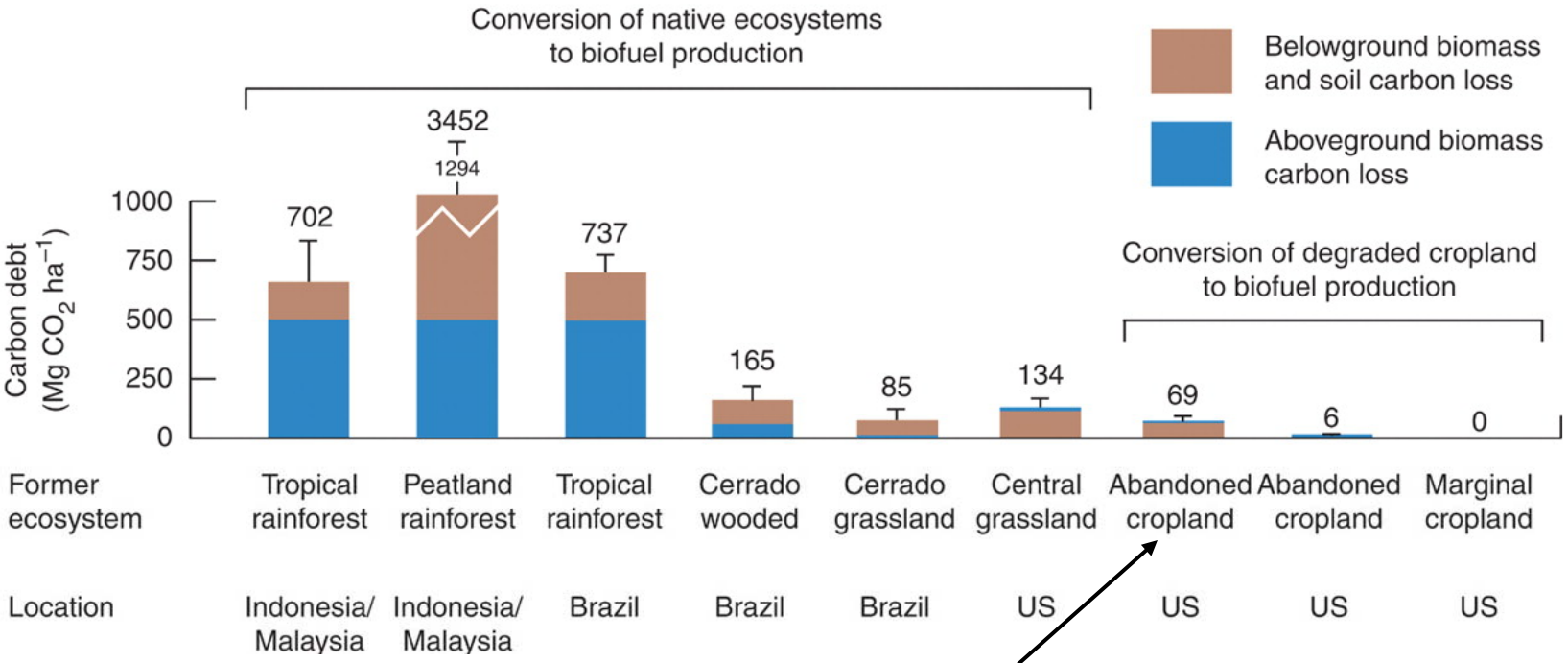


Average Share of World Exports 2002 through 2007



Response to Higher Feed Prices

- CRP smaller
  - CO2 release attributable to ethanol?
- Fewer U.S. soybean acres
  - Credit to ethanol?
- More soybeans in Brazil than would have been the case without ethanol



J. Fargione et al., Science 319, 1235 -1238 (2008)

0.6 tons/acre per year loss of soil carbon (CO2)

Land Use not the Only Market Response

- Higher crop prices attributable to U.S. ethanol will also increase yields
- Need to reduce CO2 emissions could induce industry to increase efficiency of corn and ethanol production in terms of greenhouse gas emissions.
- Can higher yields and increased efficiency offset the debt from indirect land use?

The Thought Experiment

- What if we had a world of no ethanol in 2016?
  - U.S. harvested corn and soybean acreage equal at 72.5 million acres
  - Corn yield per acre = 171 bu (today 151)
  - World demand expands to use all the corn

An Alternative Future

- Now what would happen if we produce 15 billion gallons of corn ethanol?
  - Hold world corn (or corn equivalents) and soybean use constant
  - Corn for 15 billion gallons of ethanol in U.S. comes from converting soybean acreage to corn acreage
  - New acreage needed to meet soybean demand
  - CO2 debt from conversion of land to keep food use constant

Caveats

- Unrealistic baseline
  - No food use decline due to price increase
  - Current 10 billion gallons not grandfathered in
  - No increase in land use efficiency (no increase in double cropped acreage)
- But this is the type of analysis being conducted by EPA, CARB, and the EU

Key Questions

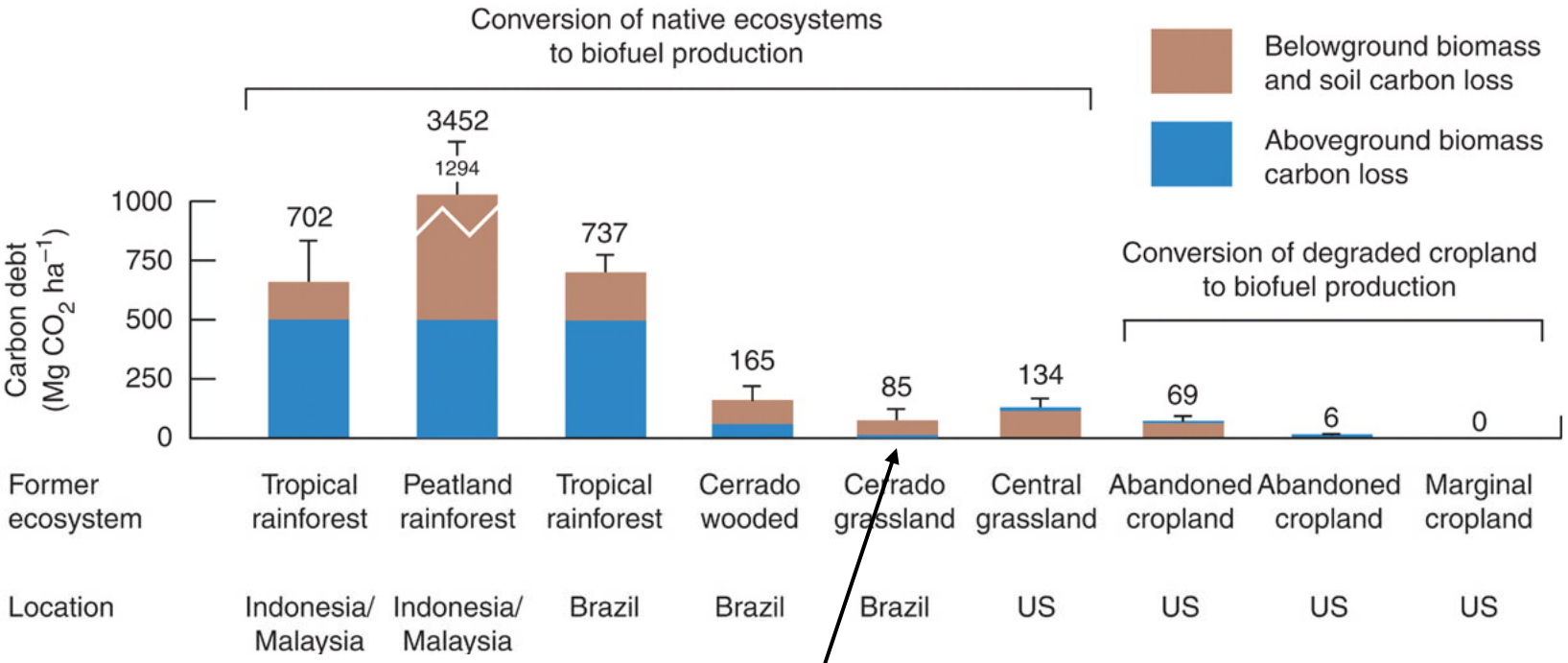
- Are greenhouse gas emissions higher or lower in scenario relative to no ethanol baseline?
- If emission higher,
  - How much higher would yields need to be to reduce emissions?
  - How much lower would life cycle analysis of ethanol emissions have to be have a net reduction in emissions?

Result

- If no carbon debt outside the U.S., the reduction in greenhouse gas emissions is 0.61 kg CO2 per gallon of ethanol: a 20% reduction in CO2 relative to gasoline
  - Why not higher? Because moving from corn-soybeans to corn-corn increases emissions of corn crop
  - All that increase in emissions is counted towards ethanol

Results

- But to hold food use constant, 11.9 million ha of soybeans needs to be grown somewhere else



J. Fargione et al., Science 319, 1235 -1238 (2008)

1700 kg per hectare loss per year loss

Results

- 11.9 million ha times 85 Mg per ha is a carbon debt of 1,011,500 million kg
- 15 billion gallons of ethanol reduces CO2 emissions by 9,156 million kg
- At this rate it takes 110 years to pay back the carbon debt
  - Fargione et al calculates a 93 year payback

What About Yield Increases?

- To get U.S. farmers to plant 102 million acres of corn will require a large price increase in the price of corn relative to soybeans
  - Make up for lower yields and higher production costs
- Higher corn prices will induce higher yields in the U.S. and around the world.
- Higher yields would reduce acres converted to continuous corn and reduce land conversion in Brazil and reduce the carbon debt
- Question: How much would U.S. corn yields have to increase to offset the carbon debt?

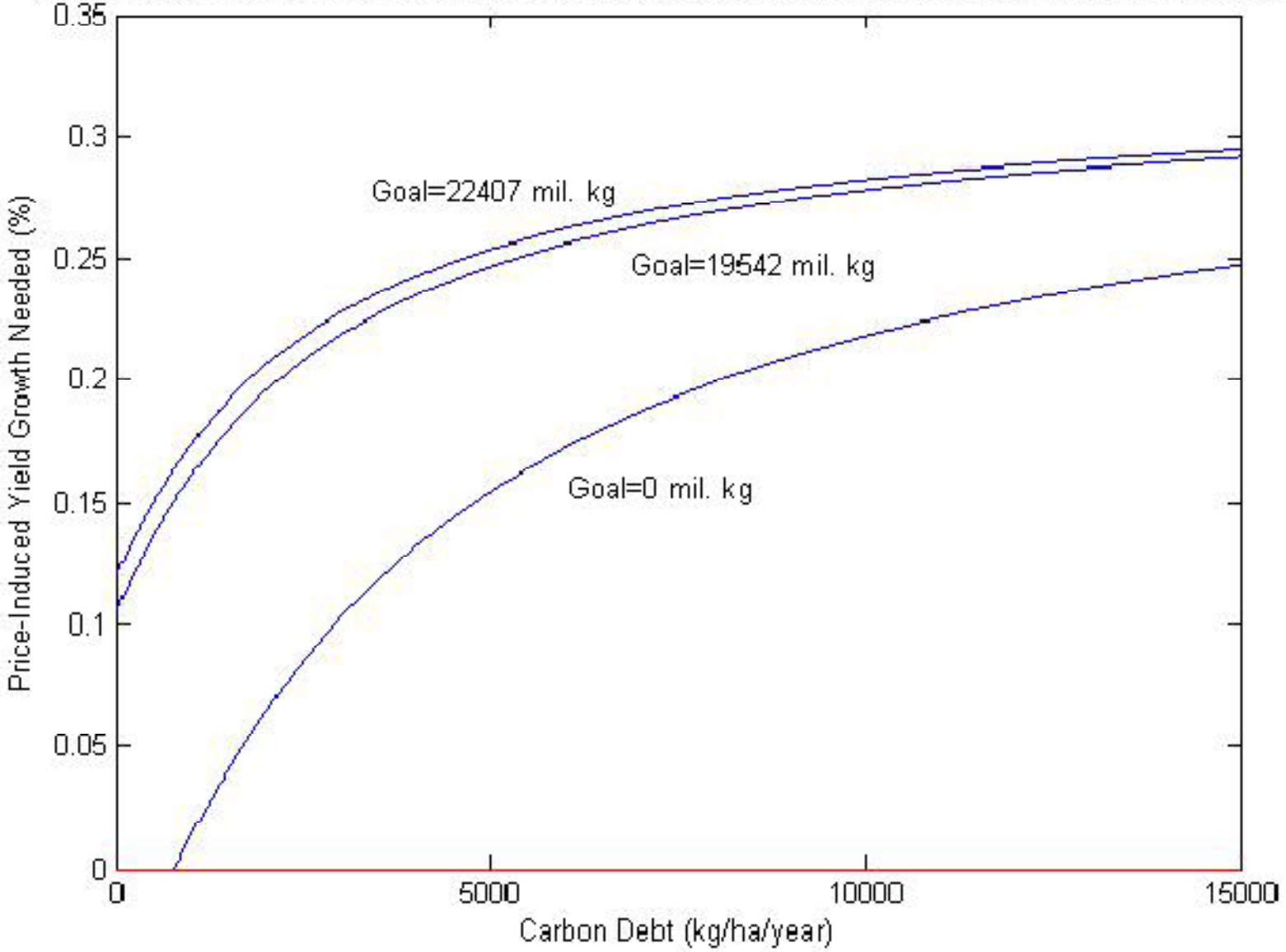
Annualize the Debt

- Suppose we want to hit a 50 year target
- That is, divide the total emissions from land conversion by 50 years and then hit a performance target after 50 years

Required Corn Yield Increases

	50-Year Greenhouse Gas Reduction Target	
Type of Land	Break-Even	20% Reduction
Idle U.S. land	4%	18%
Brazilian grassland	5%	19%
Brazilian Rainforest	25%	29%

Figure 1 Price-Induced Yield Growth Needed for Different GHG Emission Goals and Carbon Debt Level



Source: Preliminary results from Ruiqing Miao and Bruce Babcock

More Results

- Increases in efficiency of corn and ethanol production lowers the required yield increase
- If we have no increase in yield, then a 12% increase in efficiency of both corn and ethanol would offset the debt of converting Brazilian grassland in 50 years
- A 34% increase would achieve a 20% reduction target

Conclusions

- Yield increases and efficiency gains have the potential to offset effects of indirect land use
  - Must make the changes attributable to ethanol expansion
- Lots of other questions concerning
  - Timing of land conversion
  - What is in the baseline
  - What about technology adoption overseas