



# **A few key issues in determining the effects of US biofuels production on Global Land Use**

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Based on joint work with colleagues at

The Center for Global Trade Analysis

Purdue University

And

UC-Berkeley-ERG

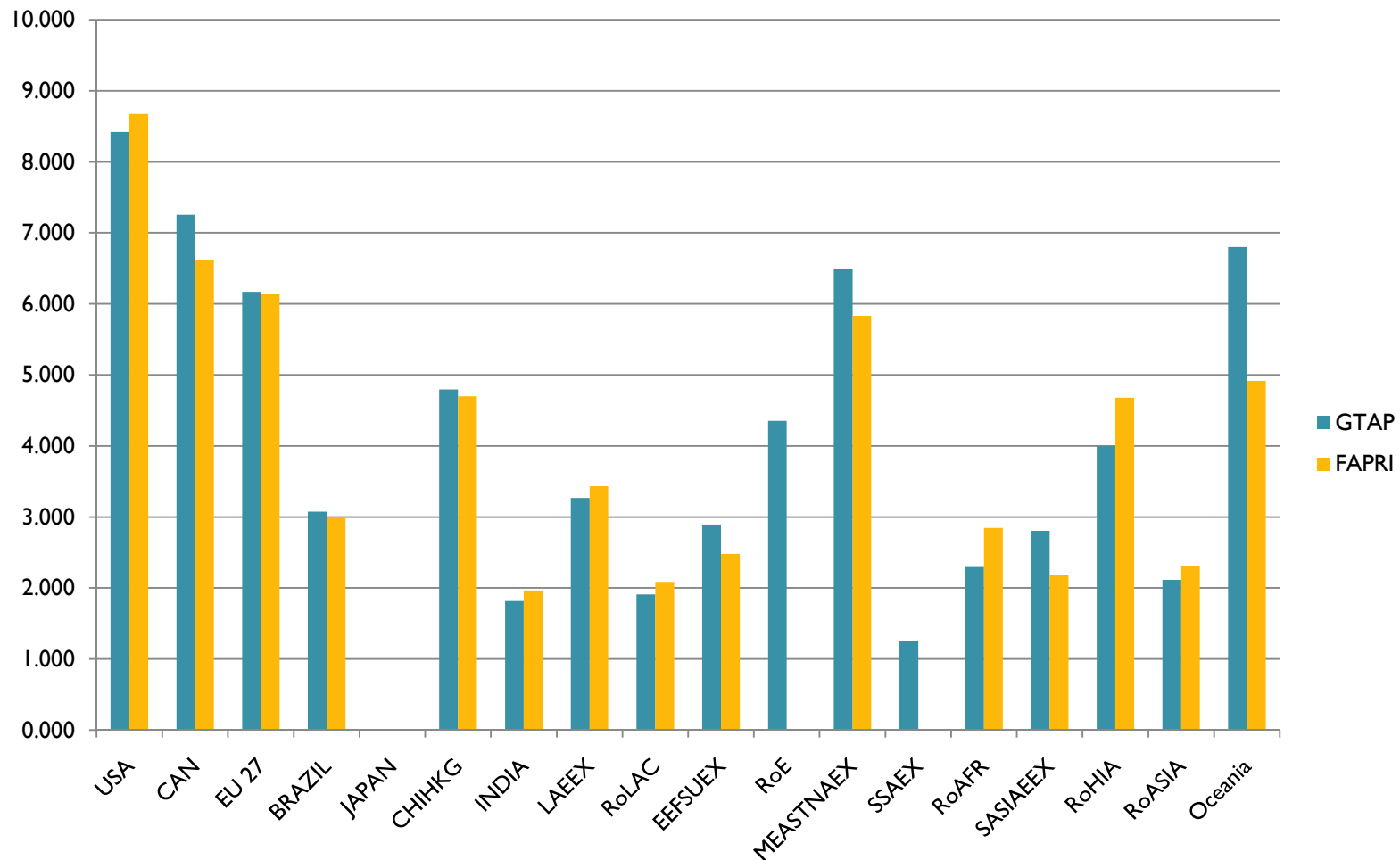
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# Selected issues

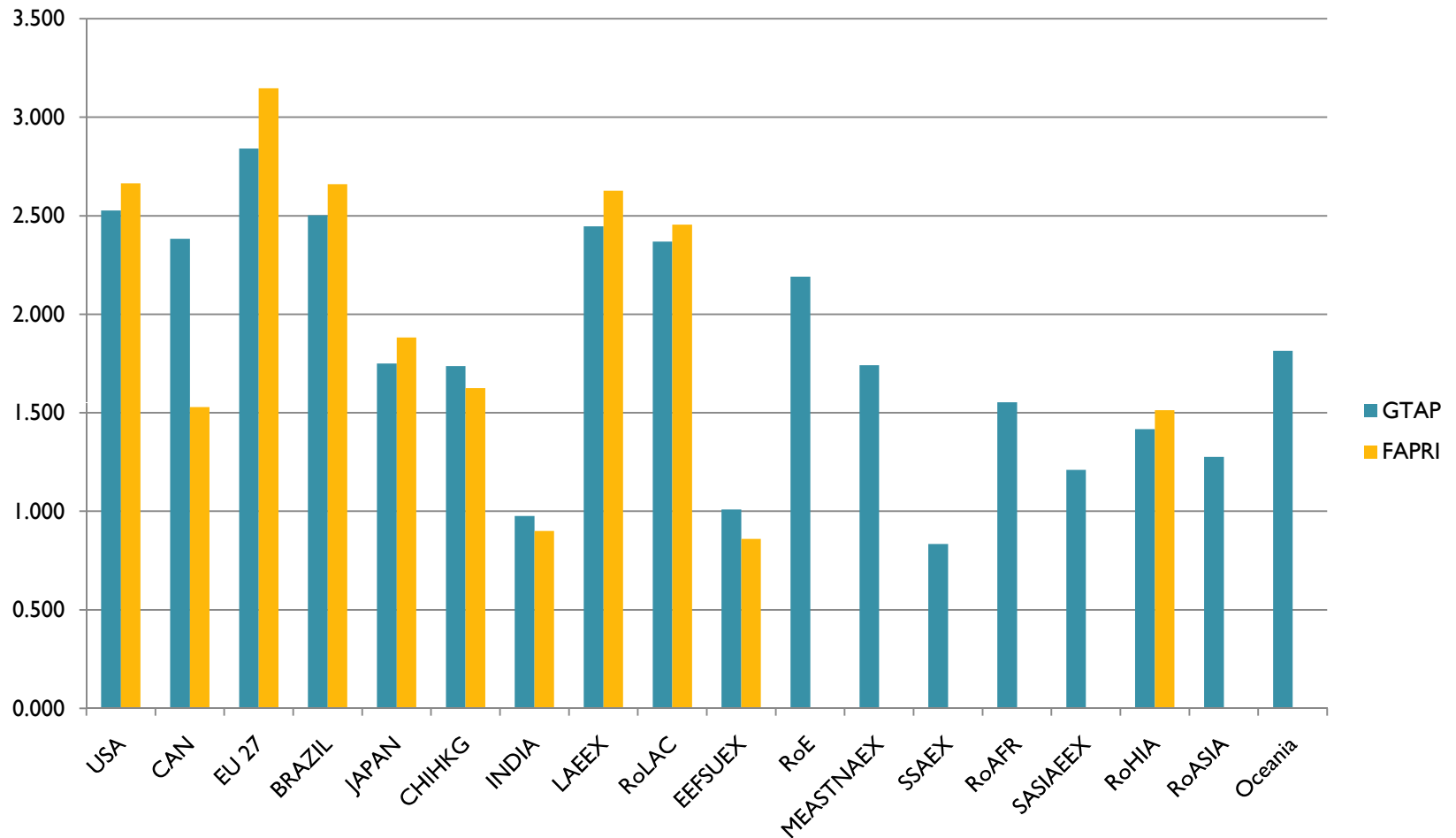
- Yields, yields, yields!
  - Spatial variation:
    - Internationally
    - Within country (by AEZ)
  - Baseline yields (*exogenously* changing over time)
  - *Endogenous* yield response to biofuels policies: intensive vs. extensive margins
- Geographic distribution of global production response to biofuels
- The impact of consumption changes on land use
- Conclusions: Quantifying the extent of our uncertainty

# There is reasonably good agreement on historical international yields



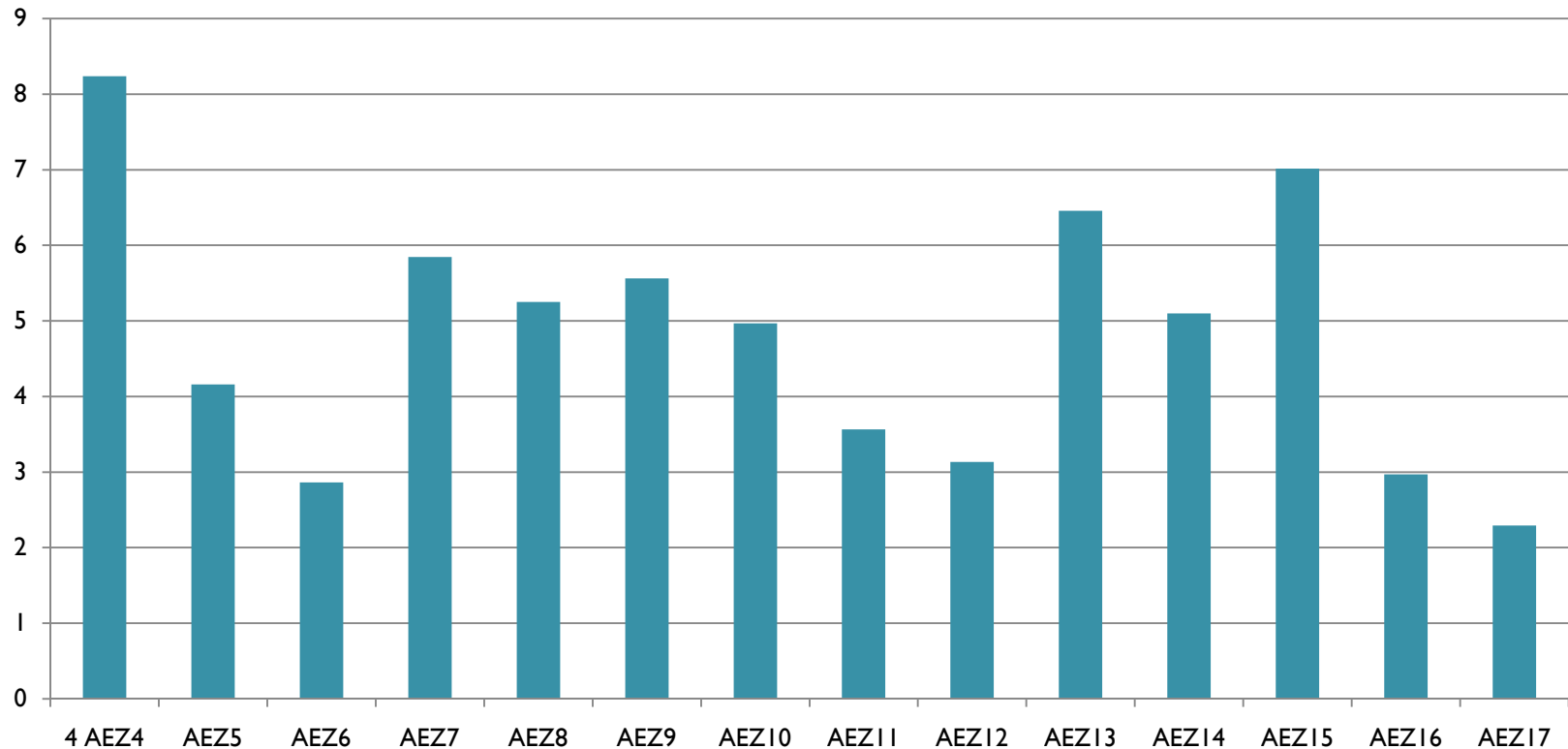
Comparison of **corn yields** (metric ton/ha) GTAP/SAGE is 1997-2003 average  
 FAPRI is from the 2001/02 marketing year

# There is reasonably good agreement on historical international yields



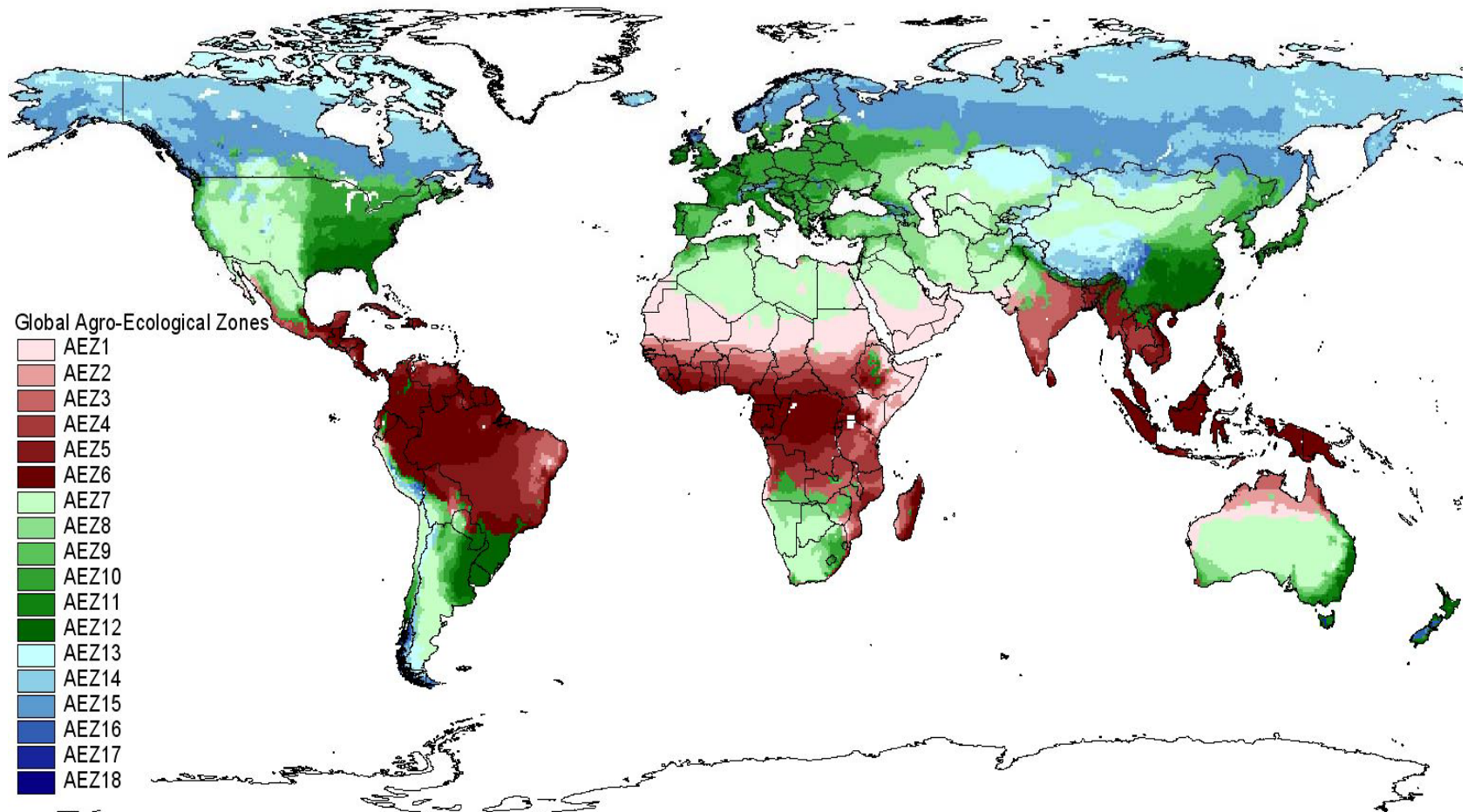
Comparison of **soybean yields** (metric ton/ha) GTAP/SAGE is 1997-2003 average  
FAPRI is from the 2001/02 marketing year

**Intra-national variation is also important:  
GTAP captures this via AEZs:  
Ignored in most global analyses**



**Corn yields** (metric ton/ha) GTAP/SAGE across AEZs for China  
(no corn is grown in AEZ18; no AEZs 1-3 in China)

# Global Distribution of AEZs



Source: Lee *et al.* 2005



## Discussion of the Baseline Yields

- GTAP analysis is based on 2001 global economic data base
- 2001 yields are lower than yields in 2007, 2017, 2022
- Can we make a simple adjustment to capture effect of higher current yields?
- If one is developing a full-blown baseline with future yields, what should we look out for?

## Simple model, one commodity (corn), two regions: US, RW

- Market clearing condition for *non-biofuel* corn demand:

$$A_C^{US} Y_C^{US} + A_C^{RW} Y_C^{RW} = D_C^{WLD}$$

- Differentiate assuming demand is constant

$$dA_C^{RW} = -[Y_C^{US} / Y_C^{RW}] dA_C^{US}$$

- Change in RW area depends on change in US corn area from biofuels, multiplied by *yld ratio*
  - If yields grow at same rate, only deflate change in US area
  - If RW yields grow more slowly, ratio rises, RW area change rises for a given area change in US

1. Start with world equilibrium: global supply = global demand

2. Now reduce US area devoted to coarse grains for food/feed

3. If RW area doesn't increase, there will be excess demand

Determining global land use change in the context of baseline yield changes

2001 Coarse Grains market (Mha and Mbu)

US			RW			World		Excess Dmd
Area	Yield	Prod	Area	Yield	Prod	Demand		
<b>Initial Equilibrium</b>								
36	335	12175	252	109	27473	39648	0	
<b>US 15bgy, no adjustment RW, no cross-commodity effect</b>								
21	335	7083	252	109	27473	39648	5092	
<b>US 15bgy, area adjustment RW, no cross-commodity effect</b>								
21	335	7083	299	109	32565	39648	0	
<b>Change in RW Area</b>			47					

4. So prices rise and RW area responds by increasing area; total rise in this case is 47 mill ha (15bgy, with no other adjustments, no byproducts, etc.); Since RW yields are about one-third of US on average

1. Now move to 2007 – US corn yields grew by about 10%, what if we simply deflate our 2001 LUC estimate by this amount? **We get: 42.5mill ha**

2007 Coarse Grains market (Mha and Mbu): yields and demand are 10% higher

GTAP estimate of RW land use change, based on higher yields

2001 est      Deflated by yields  
 46.7            0.9

**42.5**

US			RW			World	
Area	Yield	Prod	Area	Yield	Prod	Demand	Excess Dmd
<b>2007 equilibrium in presence of balanced yield and demand growth</b>							
36	369	13392	252	120	30220	43612	<b>0</b>
<b>US 15bgy, deflated by yield growth, no adjustment RW, no cross-commodity effect</b>							
<b>23</b>	369	8300	252	120	30220	43612	<b>5092</b>
<b>US 15bgy, area adjustment RW, no cross-commodity effect</b>							
23	369	8300	<b>295</b>	120	35312	43612	0
<b>Change in RW Area</b>			<b>42.5</b>				

**Conclusion: The only adjustment required is to deflate the initial land use impulse in US**

2. Or we can redo the entire baseline – in this case assuming equal growth in yields and demand; so global supply = global demand

3. With higher yields the reduction in US land area is smaller, as is the LUC in RW; **which is also equal to 42.5m ha**. So in this case it is sufficient to deflate the final result by the yield growth.

1. Finally, assume no growth in RW yields (and adjust global demand down to get revised equilibrium)

US			RW			No growth in RW Yields			World	
Area	Yield	Prod	Area	Yield	Prod	Demand	Excess Dmd			
<b>2007 equilibrium in presence of UNbalanced yield and demand growth</b>										
	36	369	13392	252	109	27473	40865	0		
<b>US 15bgy, deflated by yield growth, no adjustment RW, no cross-commodity effect</b>										
	23	369	8300	252	109	30220	40865	2345		
<b>US 15bgy, area adjustment RW, no cross-commodity effect</b>										
	23	369	8300	299	109	32565	40865	0		
<b>Change in RW Area</b>				47						

**Conclusion: If only US yields grow, then land use change in RoW is back to its 2001 value**

2. Now we are back to the 2001 value of RW land use change.



## Endogenous variation in yields is also important

- Intensive margin: producers respond to biofuels mandate by boosting yields
  - Historical yield response for corn pretty high (as high as 0.7)
  - More recent estimates much lower (avg. 0.25)
  - We use 0.25 yield elasticity
- Extensive margin: producers expand onto new area, yields are likely to fall
  - Little empirical evidence here; more work needs to be done
  - We assume 0.66 (need 3 ha of newly converted land to replace production lost from 2 ha of existing land)
- These parameters are key to the land use change results

## Intensive margin dominates in our results; yields rise worldwide; reduces area required

### Decomposition of Global Crop Output (% change)

Crop	Total	Area	TotYield	YieldInt	YieldExt
Cgrns	6.05	4.94	1.06	1.54	-0.47
Oilseeds	0.10	-0.35	0.45	0.64	-0.20
SugarCrp	-0.17	-0.62	0.45	0.31	0.14
OthGrain	-0.25	-0.57	0.32	0.27	0.05
OthCrops	-0.25	-0.36	0.12	0.22	-0.10

Results are sensitive to yield parameters:  
13.25bgy corn ethanol

Cropland conversion in mill ha

<i>Params</i>	Base	"FAPRI"
Yld	0.25	0
ETA	0.66	1
<i>Cropland Conversion</i>		
<b>USA</b>	1.59	1.256
shr forest	0.34	0.18
shr pasture	0.66	0.82
<b>World</b>	4.19	4.39
shr forest	0.19	0.05
shr pasture	0.81	0.95

- FAPRI has no intensive or extensive yield response; yields are exogenous
- FAPRI yield assumptions give similar global cropland conversion, but less in the US and far less forest land conversion

# Geographic Distribution of Production

- Two views of the world:
  - “FAPRI”: one global market for agricultural commodities; when demand rises, supply is equally likely to come from India as from US, regardless of source of shock
  - “GTAP”: there is a geography of international trade – characterized by sticky bilateral trade relationships; increased demand in US market most likely to affect US market, followed by key trading partners/competitors in our key foreign markets
- Illustration: share of global cropland conversion in US (China) fol
  - GTAP std params: US=38%; CHN=0.9%
  - “FAPRI1” (GTAP w/high trade elasticities): US=17%; CHN=1.6%
  - “FAPRI2” (GTAP w/exog yld & very high trade elasticities): US=14%; CHN=2%



# Impacts of Reduced Consumption

- Impact of reduced consumption due to higher prices plays a significant role in reducing land requirements for biofuels; but largely overlooked
- However, most price responsive demand is in low income countries, where rates of poverty and malnutrition are highest; What if prevented reduction in consumption via food subsidies? In our work with UCB-ERG:
  - We estimate twice as much forest land conversion and
  - 50% higher GHG emissions from LUCwhen food consumption is fixed (does not adjust to higher prices)



# Conclusions

- While estimation of global land use impacts of biofuels is a challenging task, we have made quite a bit of progress over the past year
- Still considerable uncertainty, but we can now quantify this in terms of parametric uncertainty (parameter distributions are still pretty broad); this allows us to undertake Systematic Sensitivity Analysis and attached confidence intervals to our results
- For example, in work with UCB for CARB, we find that the mean estimate of global LUC-based emissions is more than twice as large as the associated standard deviation which is generally taken as an indication of statistical significance in the literature
- Likely that this confidence interval will tighten up with additional empirical work