Life Cycle Associates LLC

Review of Economic Models Used to Assess Land Use Effects

CRC Project E-88-3

CRC Workshop on Life Cycle Analysis of Transportation Fuels

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Study Objectives

- Explain agro-economic LUC modeling
- Describe mechanisms in leading LUC models
  - GTAP
  - FASOM
  - FAPRI
  - MIRAGE BioF
- Identify key factors driving LUC
- Recommendations

Study Team

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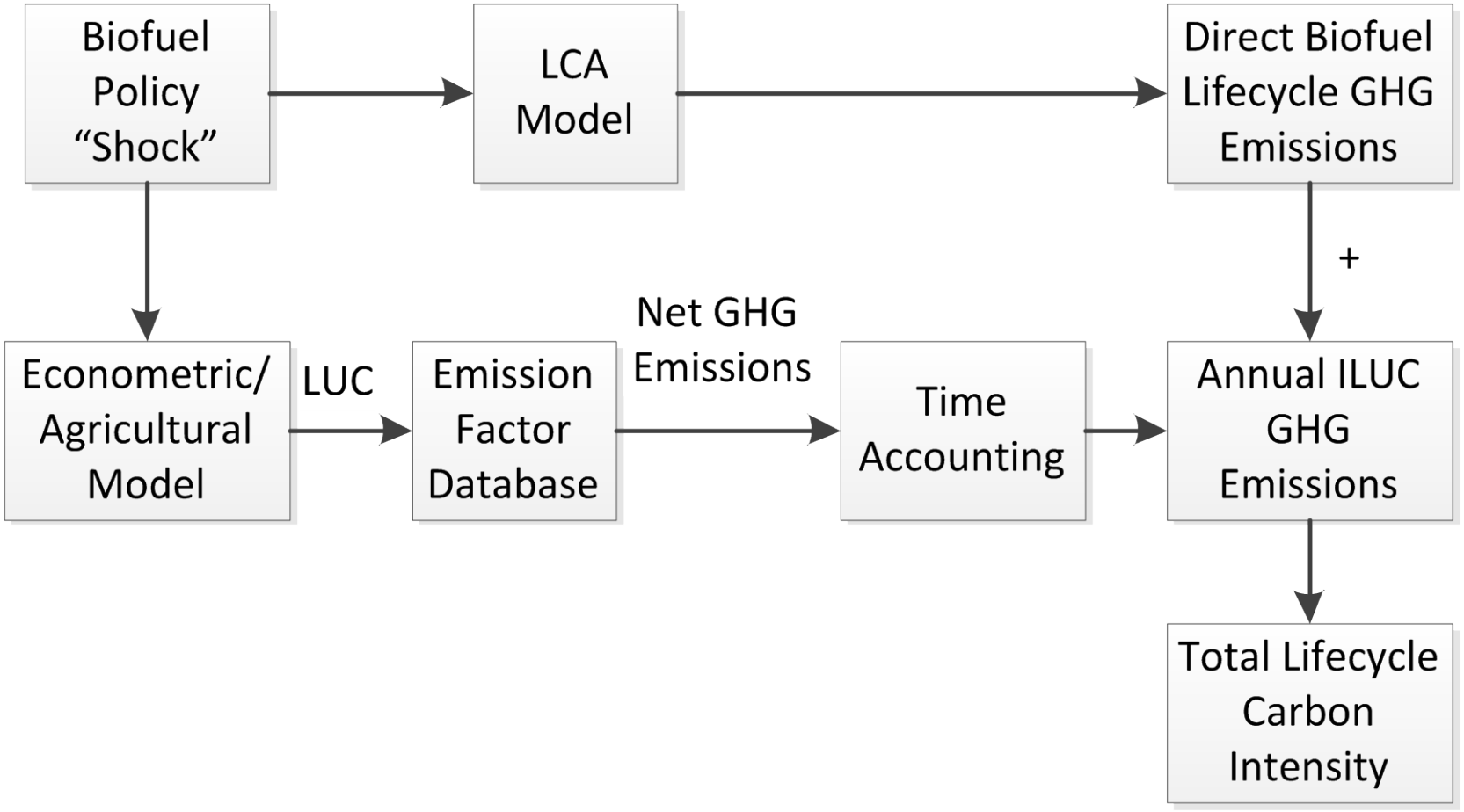
Sponsor: Coordinating Research Council, E-88-3

- Christopher Tenant, CRC, Project Manager
- Phil Heirigs, Chevron, Review lead

Outline

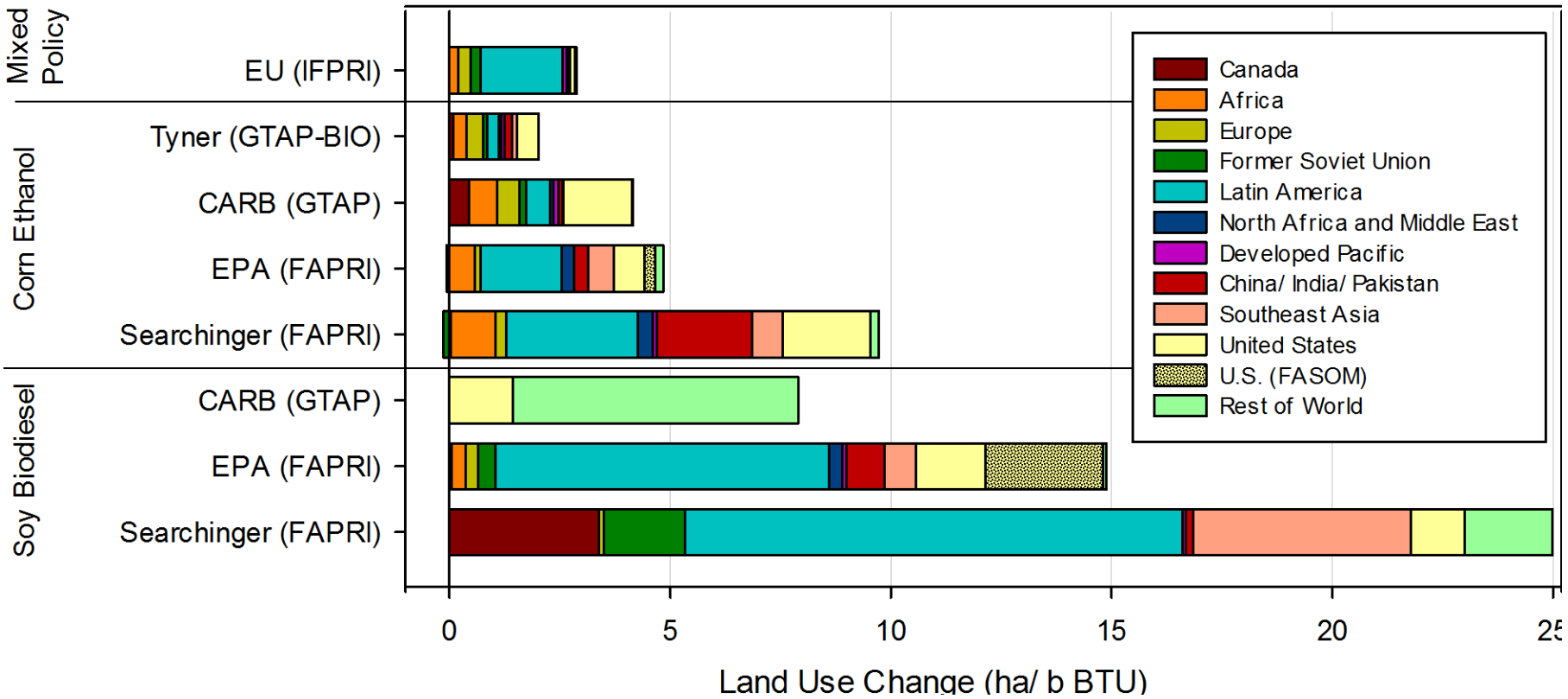
- LUC Primer
- LUC Models
- Key factors driving LUC
- Recommendations

LUC Approach

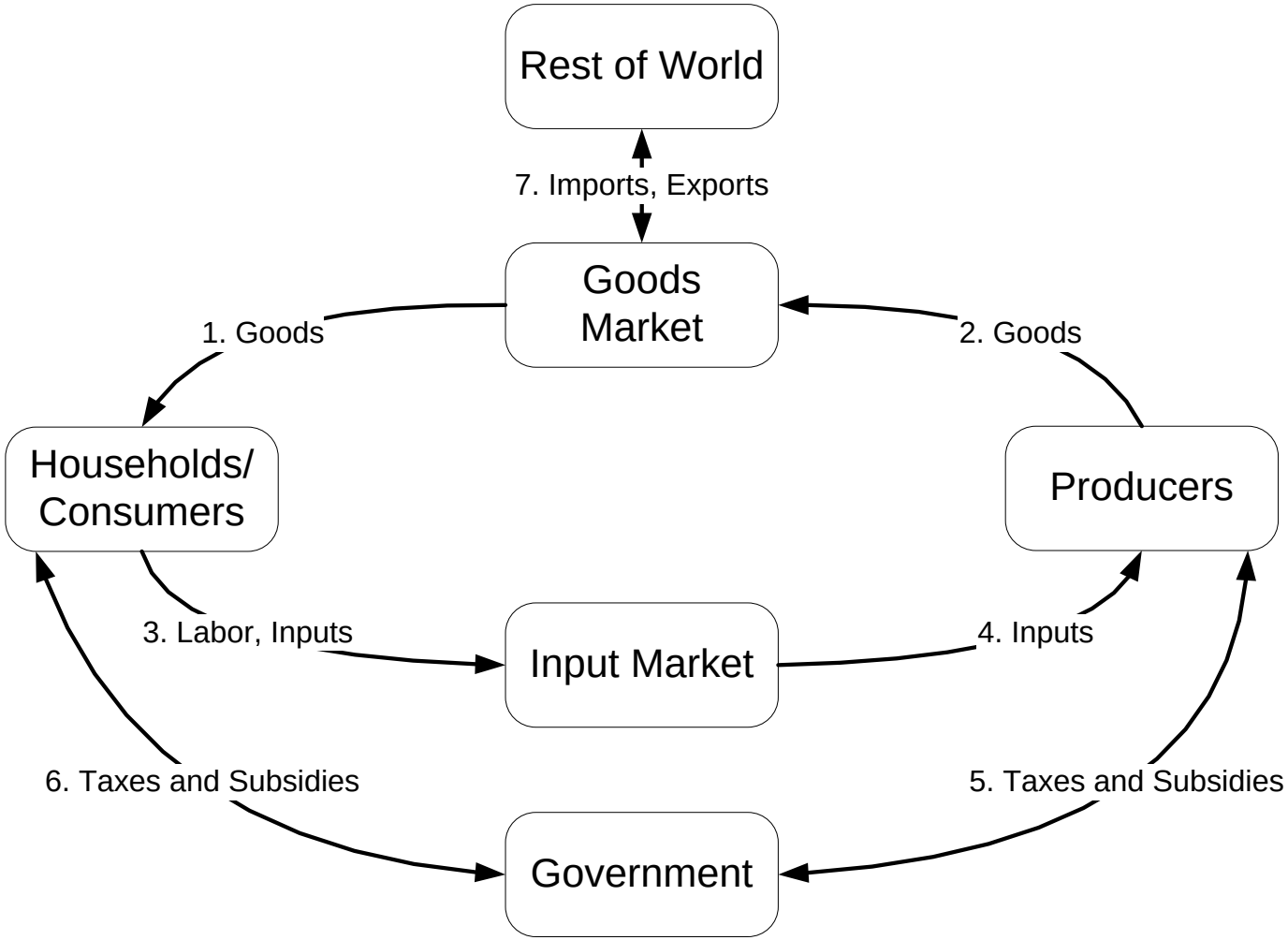


Comparing LUC Results

Draft

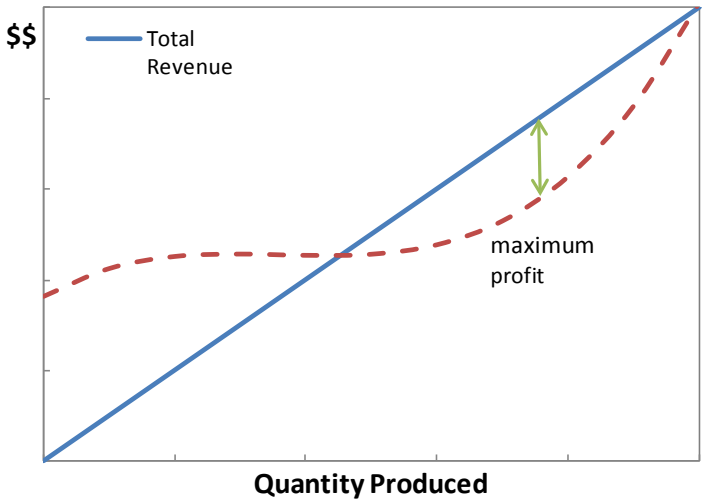


Macroeconomic Modeling

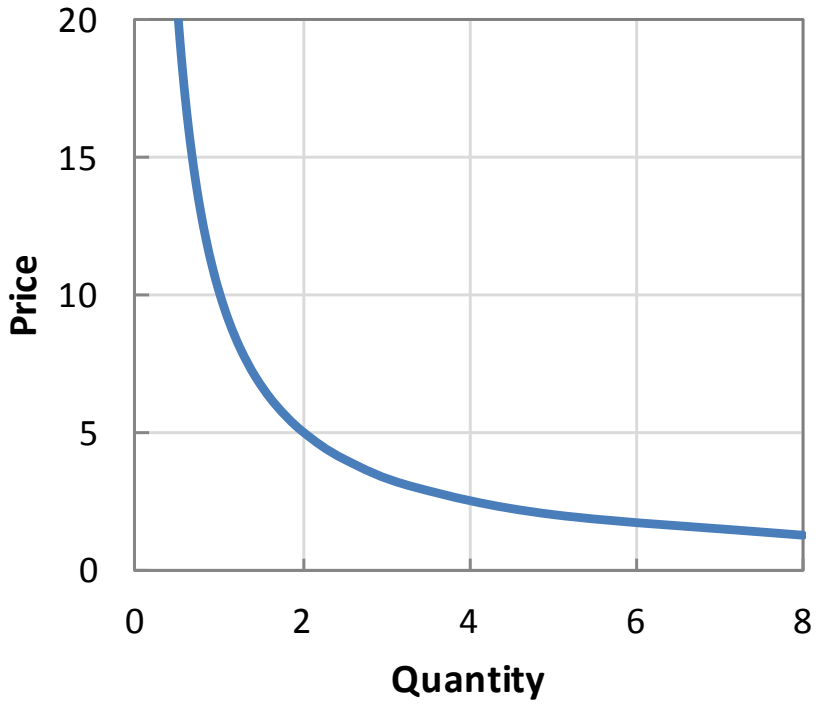


Supply/Demand

Profit Optimization



Constant Elasticity Demand Function



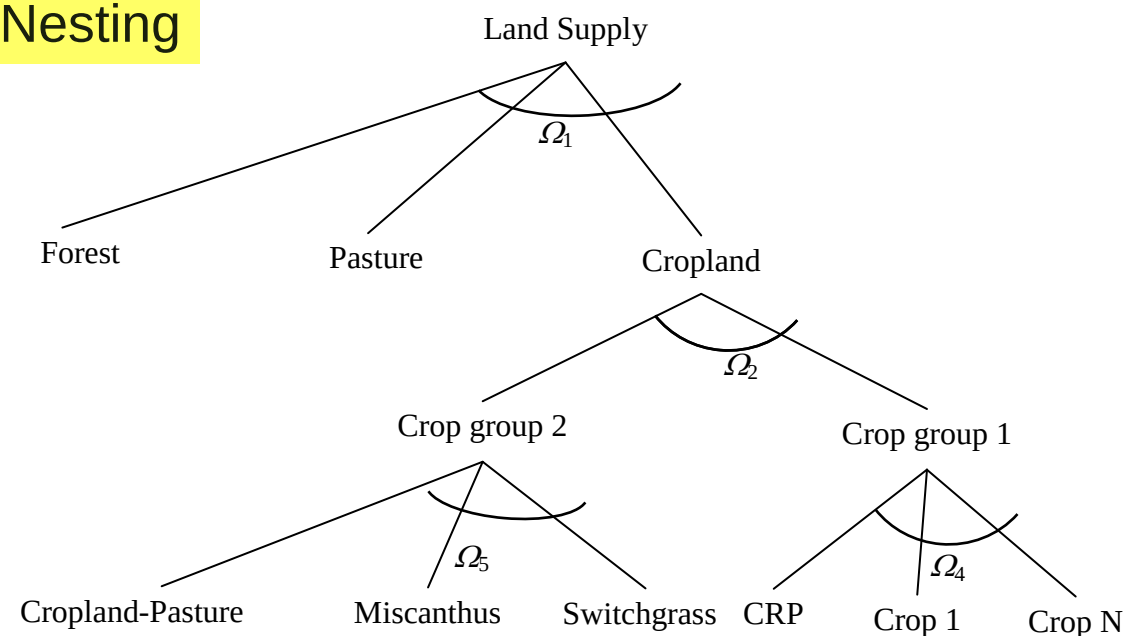
Product and Land Substitution

Substitution Ratio

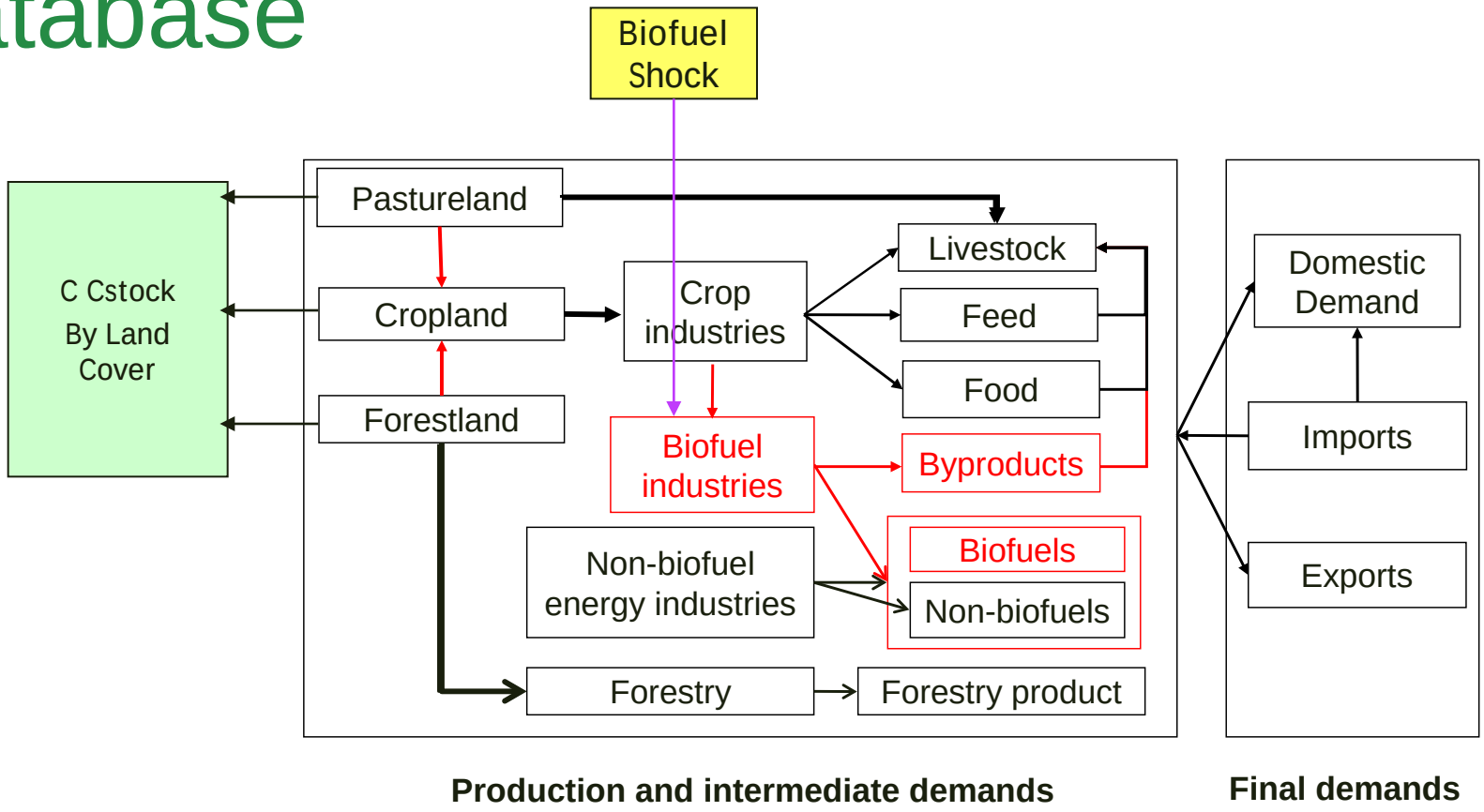
DGS_{swine} = 0.577 corn + 0.419 SBM

Source: GREET_1

Nesting



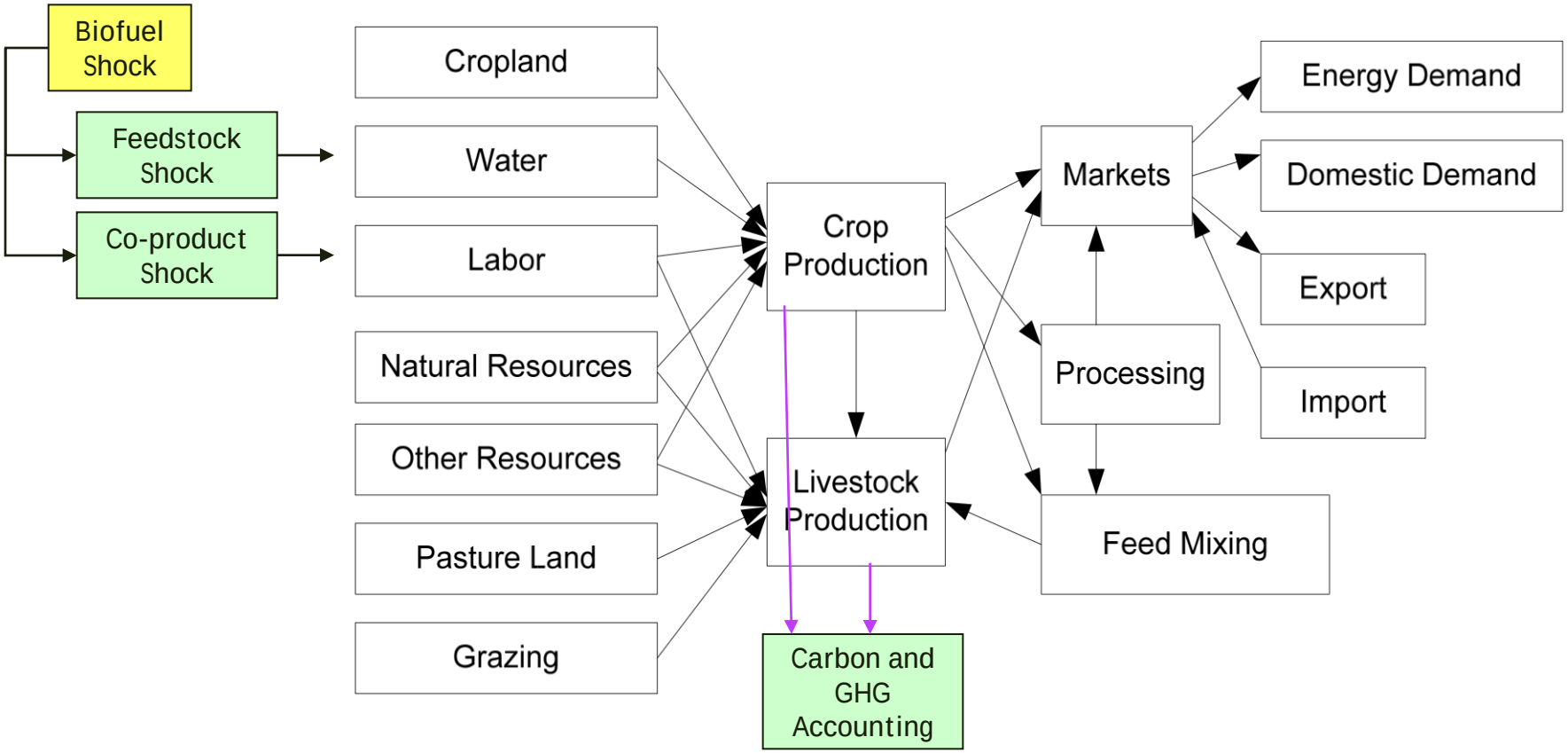
GTAP model and modifications in database



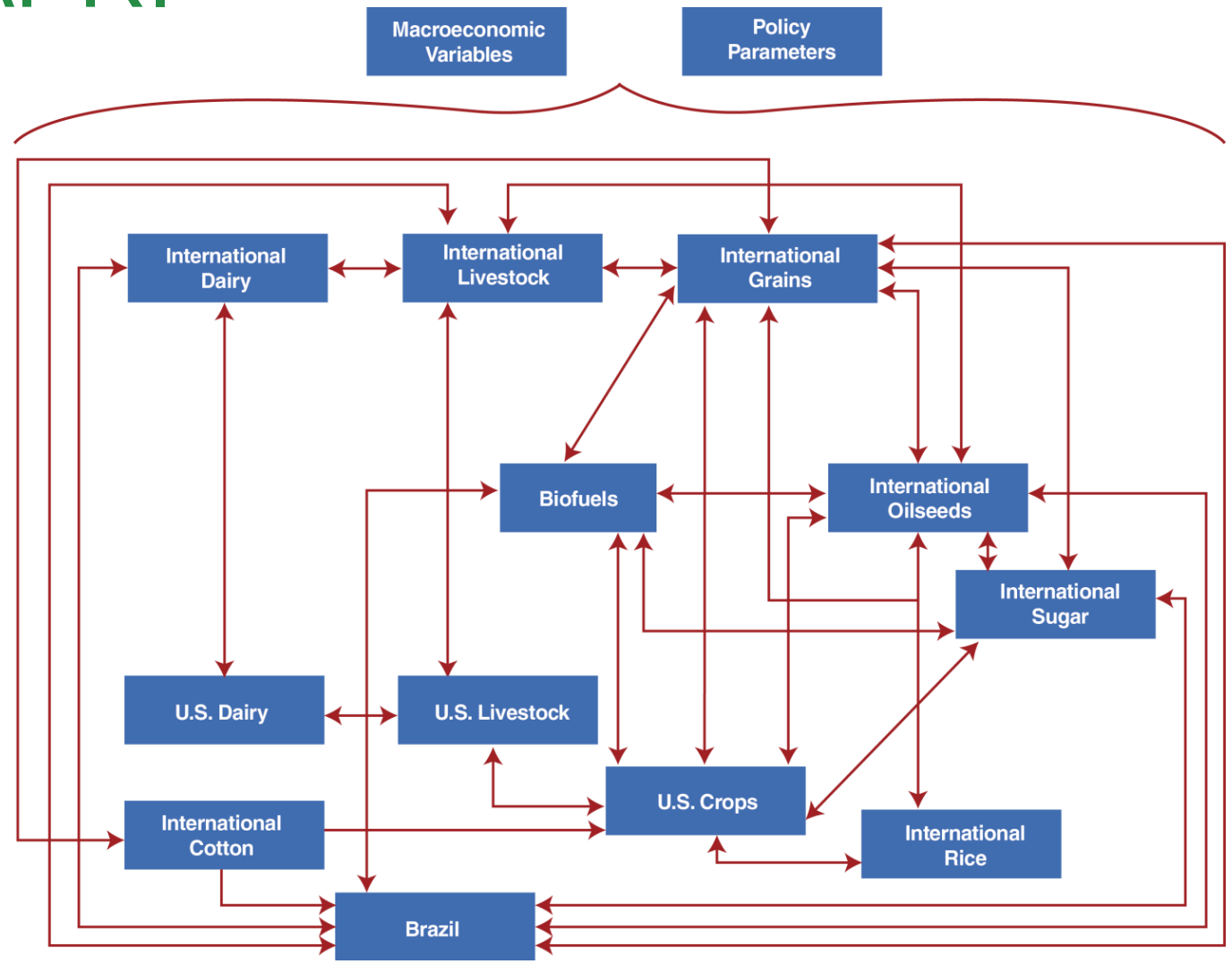
Econometric Data by Sector

VDFA	1 CrGrains	2 OthGrains	3 Oilseeds	4 Sugarcane	5 Livestock	6 Forestry	7 Ethanol	21 CGDS	Total
1 CrGrains	8144.4	165.3	102.9	39.6	28927.8	73.5	1290.8	49.7	70317.8
2 OthGrains	91.1	13829.3	284.2	43.5	28236.7	91.8	0.2	85.8	135630.8
3 Oilseeds	62.9	55.1	2954.1	43.1	9222.1	31.6	0	107	42209.8
4 Sugarcane	25.5	41.2	36	1570.7	437.1	32.6	0	112.7	28505.8
5 Livestock	4468.9	7989.9	1939.2	752.2	31039.5	371	0.2	16042.8	445569
6 Forestry	115.8	221.7	76.8	50.8	699.1	9455.4	0	6406.5	98893.5
7 Ethanol2	0.1	0.1	0	0	0.1	0	0	0.1	13.7
8 OthFoodPdts	387.4	923	517.2	304.3	94801.6	1073.5	1.3	1378.6	460545.8
9 ProcLivestoc	156.6	283.9	105.8	99	3394.2	491.8	0.2	928.3	268690.2
10 OthAgri	1097.9	3262.3	772	230.4	44284.5	785	1	3809.8	552694.3
11 OthPrimSect	226.2	225.1	83	71.3	863.3	112.6	0.3	2087.1	266413.5
12 Coal	2.1	5.3	1.3	0.4	103.3	22.1	0	0.1	77901.9
13 Oil	0	0	0	0	1.1	0.1	0	0.6	192707.4
14 Gas	7.4	18.8	7.1	2.5	94.9	16.9	0	1.1	154582
15 Oil_Pcts	1786.7	2457.3	1006.7	423.5	5628.3	1976.6	0	4.4	747324
16 Electricity	1392.1	5088.9	1306.9	710.5	6427.6	655.6	406.3	3.6	829534.8
17 En_Int_Ind	10377.7	13462.5	5898.1	2335	9469.8	2134.6	258.5	16947.9	2648100.9
18 Oth_Ind_Se	17519.5	23377.4	10529.4	4652.3	88500	27756.3	87.9	5607689	22836748.8
19 Ethanol1	0	0	0	0	0	0	0	0	1967.7
20 DDGS	0	0	0	0	429.2	0	0	0	429.2
22 BDBP	0	0	0	0	162.3	0	0	0	162.3
Total	45862.3	71407.3	25621	11328.9	352722.5	45081.1	2046.7	5655655.1	29858950.1

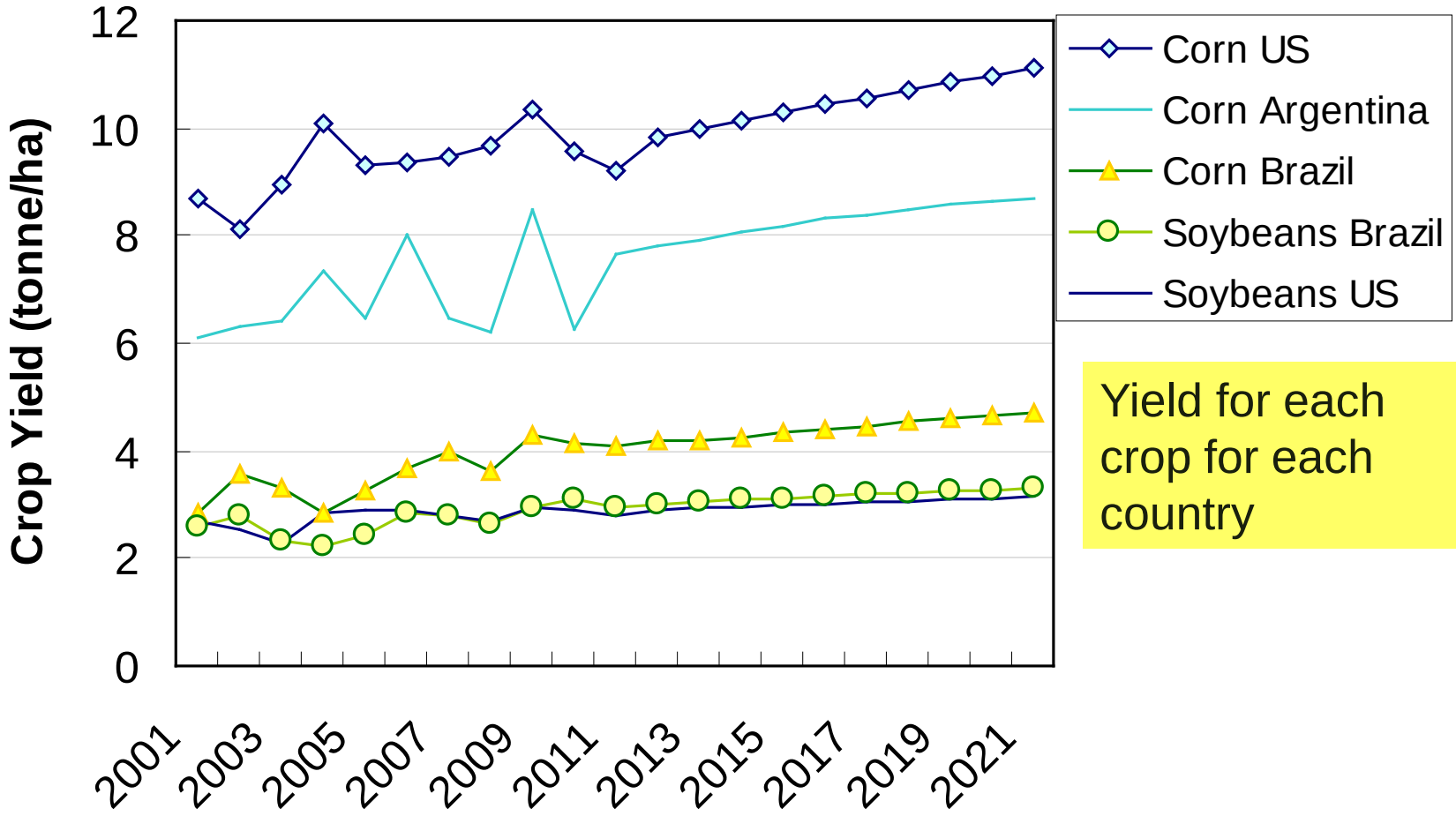
FASOM Agricultural Structure



FAPRI

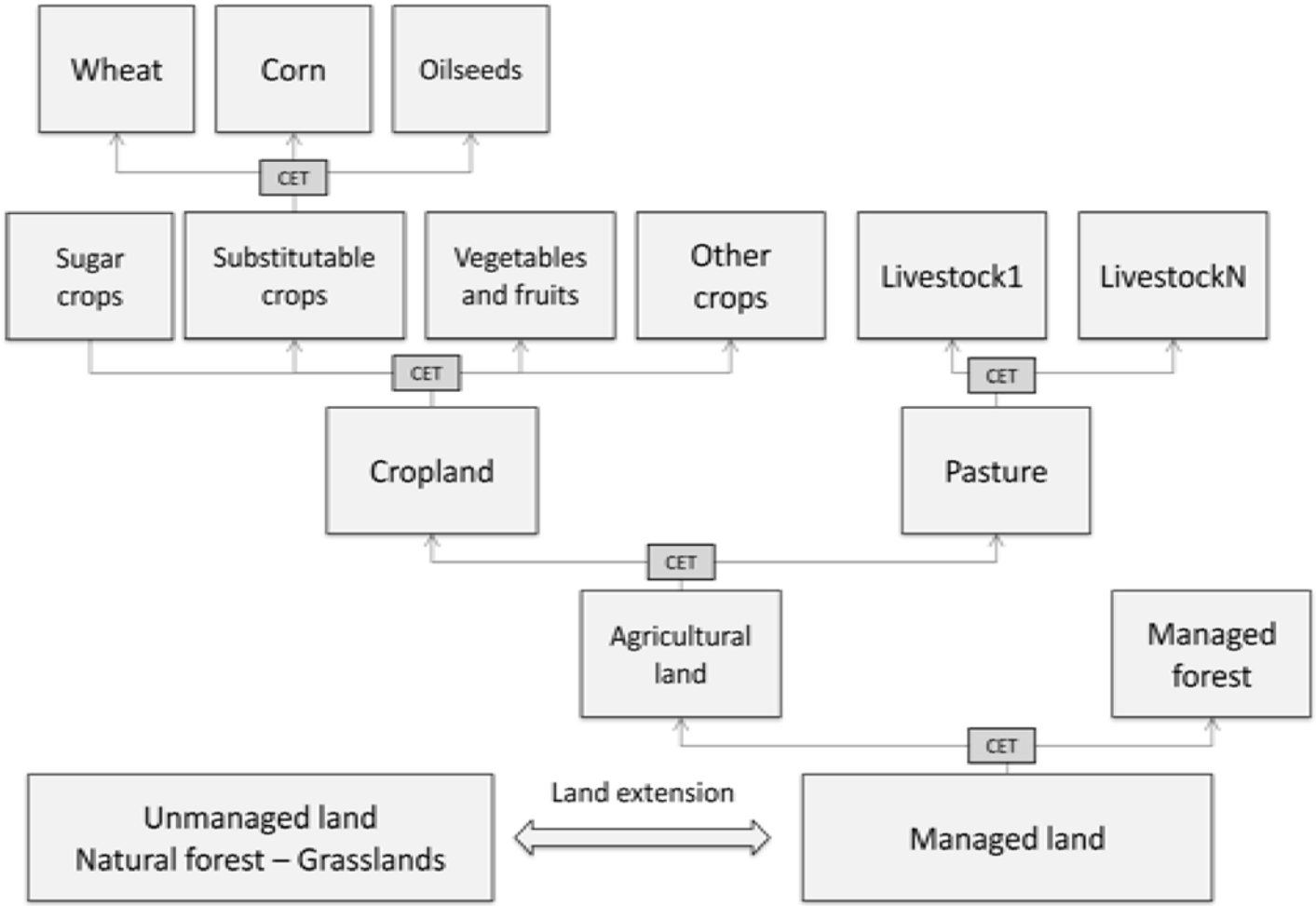


Yield Projections



Yield for each crop for each country

MIRAGE



Model Attribute	GTAP	FASOM	FAPRI	MIRAGE-BioF
Model Input (Shock)	Shock with Surrogate Subsidy	Exogenously biofuel demand	Adjusts Petroleum Price or Subsidy	Shock with Surrogate Subsidy
Model Calculation	Solves for price and quantity when supply equals demand in each of the economic sectors (including the biofuel sectors) by AEZ.	Solves for price and quantity in 5-yr increments when supply equals demand for each ag and forestry commodity at the county level.	Solves for prices that clear the market, i.e., equalizing supply to demand, in each region and each commodity market.	Solves for price and quantity when supply equals demand in each of the economic sectors (including the biofuel sectors) by AEZ.

Model Attribute	GTAP-BIO	FASOM	FAPRI	MIRAGE-BioF
General vs. Partial	General	Partial: U.S. Forestry and Agriculture	Partial: Agriculture Sector	General
Geographic Coverage	World by AEZ	United States by county	World by political borders	World by AEZ (14 Regions)
Land Cover Types	Cropland, forest, pasture. Cropland-Pasture included for US and Brazil only.	Cropland, Cropland-Pasture, Forest-Pasture, Rangeland, Forest, Developed, CRP	Cropland, Pasture, Forest, Barren	Cropland, Managed Forest, Pasture
Economic Sectors	57 Economic Sectors	Agriculture, Forestry	Agriculture, Biofuels, Livestock, Dairy	55 Economic Sectors
Static vs. Dynamic	Static	Dynamic	Dynamic	Dynamic
Trade Assumptions	Armington Elasticities	Homogeneous Goods	Homogeneous Goods	Armington Elasticities
Time Frame	Medium term	100 years with solutions every 5 years	10-15 years	Medium term

Summary of Key Parameters

- Cumulative shock
  - U.S., EU, multiple biofuels
  - What is being modeled (policy or fuel use)
- Land cover selection
  - Pasture intensification
  - Amount of forest
- Elasticity – supply/price
- Elasticity – land substitution
- Elasticity – demand mitigated
- Crop/Product Substitution

Model Configuration

- Partial vs General Equilibrium
  - Closed system tracks available land (GTAP, FASOM)
  - FAPRI modelers are aware of limited land resource
    - How would 30 billion gal shock be treated compared to 10 billion gal?
    - GTAP has been run in partial equilibrium mode
- Cumulative shocks
  - All things remaining equal, more biofuel use means more land
  - On the margin, more expensive land, higher carbon stocks
  - Price effects are also important

Biorefinery Yield and Products

- Co-products
  - DGS, soy bean meal, palm kernel, rapeseed meal
    - Displace other agricultural products
    - Displacement ratios or elasticities of substitution drive model
    - GTAP DGS = corn, FAPRI displacement ratios
    - DGS to soy is a big effect
    - Corn oil to soy oil would also be a big effect
- Model data source
  - Aggregate econ (GTAP) CAS sectors
  - Ag supply/demand (FASOM, FAPRI) FAO, UN area production
    - How many cows, milk, etc..
    - Regression equations, many outside sources
    - Economic data services
    - Bottom up calculations, engineering data
    - Tariff assumptions.. USDA policy
    - Ag land = f(price data)
    - Feedstock = f(price or 1/yield)

Land Categorization

- Land categorization
  - Pasture intensification, carbon stock type, land rents
  - Substitution of land types
  - Fraction of forest, this is the biggest driver for carbon stocks
  - Cattle stocking rate, small change in stocking rate, avoid going into forest, how do you detect what is actually happening?
  - Where is the new Ag area? Is it encroaching on forest or other?
- Model drift
  - Land use varies with model shock, this is the point of the LUC modeling exercise
  - Plant yields can also change (GTAP) gal/bu, lb DGS/gal
  - Extreme inputs are an issue

Yields and Elasticities

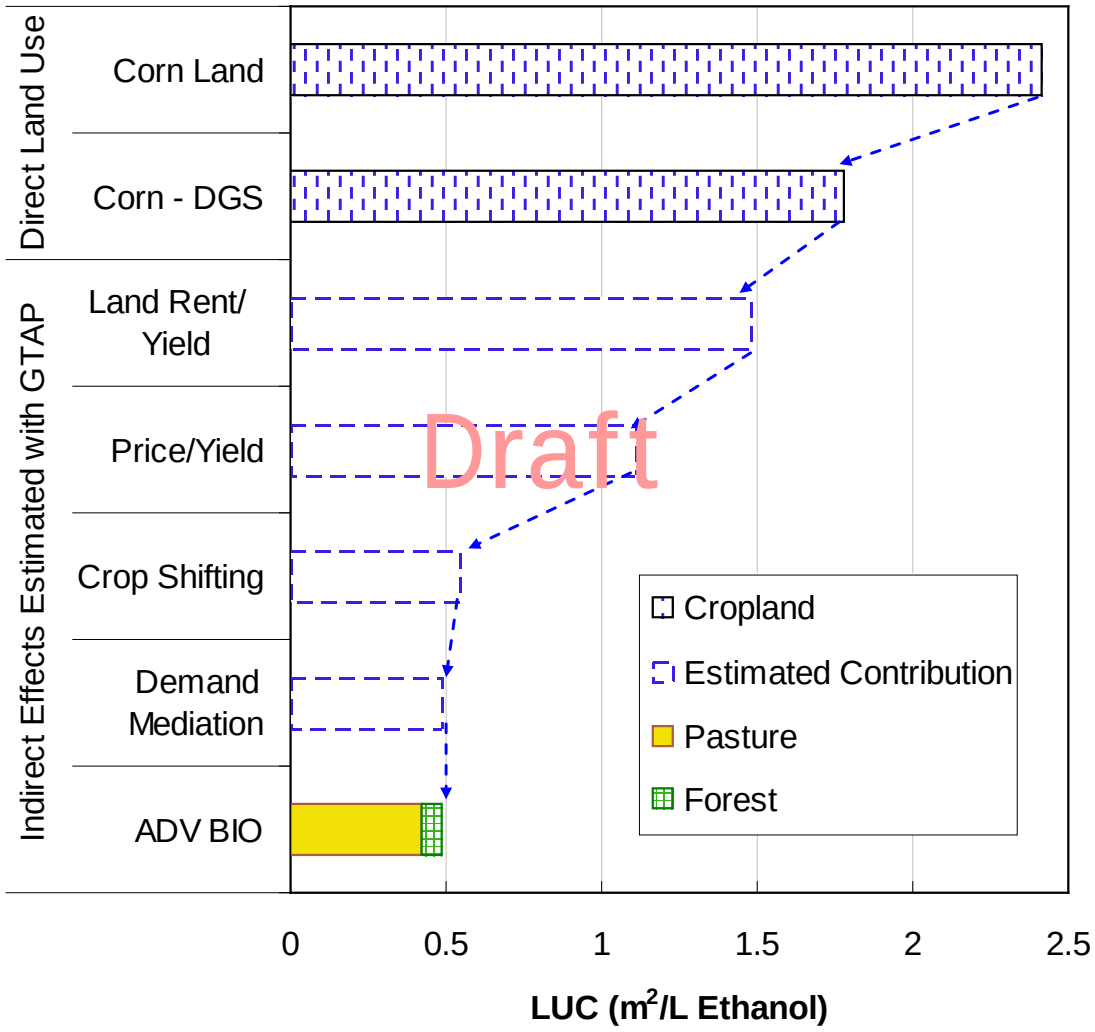
- Supply/ Price
  - Switch to other crops
  - Shifts in commodity demand
    - Beef to poultry
    - New types of pastry and cooking oils
  - Price rationing
- Yield
  - Yield improvement as price increases
    - Higher cost of inputs, work harder to collect crop
  - Technology based yield improvement

What should models consider?

- Policy is introduced and consumers and firms follow their incentives based on that policy to achieve a market outcome.
- Biofuel volumes
  - Policy driven or market driven?
  - Cumulative policy effects
- Trends in agricultural markets
  - Growth in meat consumption
  - Shift from beef to poultry
  - Oils and fats for pastry, confection, cooking
- Constraints on agriculture
  - Land restrictions, urban sprawl restrictions
  - Wet land protections
  - Forest protections

Contribution of Parameters to LUC

- Move from direct LUC to GTAP result
- 158 bu corn/acre
- Credit for 5.4 lb DGS/gal ethanol
- Interim shifts are estimates
- Tyner (2011) result (ADV BIO model)



Recommendations

- Calculate effect of key parameters
  - GTAP Runs
  - Infer effects from more complex models
  - Determine yield, crop switch, demand mediation effects
  - Determine cumulative shocks
- Improve treatment of land cover type
  - Cropland pasture outside Brazil, U.S. for GTAP
- Enhance treatment of co-products
- Examine historical data to validate models
- Enhance reporting of interim metrics