

Changes in the GTAP Modeling Framework and Data Base in its Application to Biofuels and Global Land Use Change

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October 2013

GTAP model and modifications in database

- **First generation** biofuels including: grain based ethanol, sugarcane ethanol, and biodiesel along with DDGS (co-product of grain ethanol) and meals (co-product of vegetable oil) have been introduced into GTAP **database**.
- **Second generation** biofuels including ethanol and bio-gasoline produced from corn stover, miscanthus, and switchgrass have been introduced into GTAP **database**.
- Several sectors have been **split**, and **new** sectors are introduced into the data base to model biofuel industries and their related activities **more accurately** (food, feed, crude & refined vegetable oil, corn stover, dedicated crops, soybeans, rapeseed, palm oil, sorghum).

GTAP model and modifications in household demand

Household Demand for Private Goods

Energy Composite

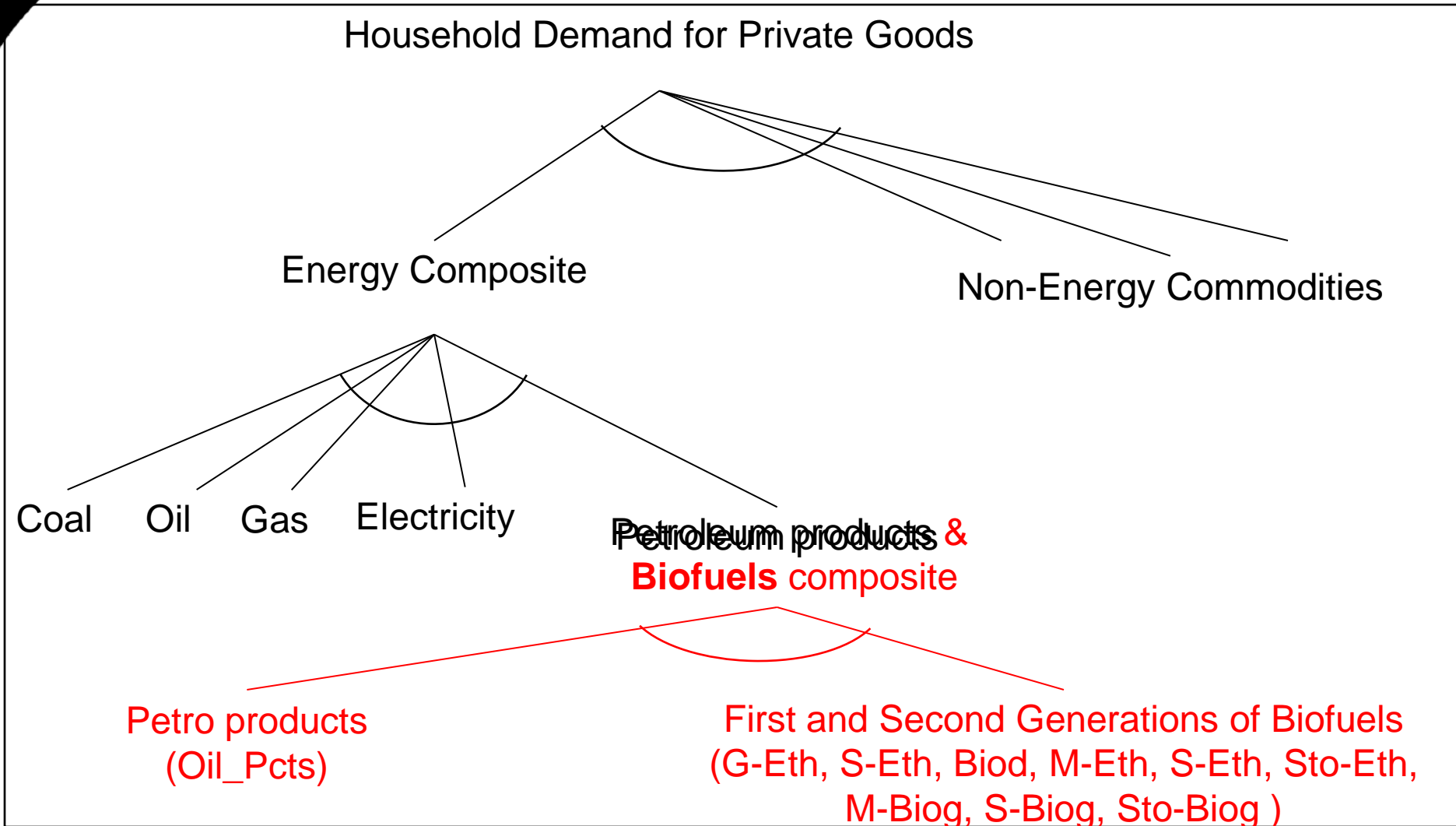
Non-Energy Commodities

Coal Oil Gas Electricity

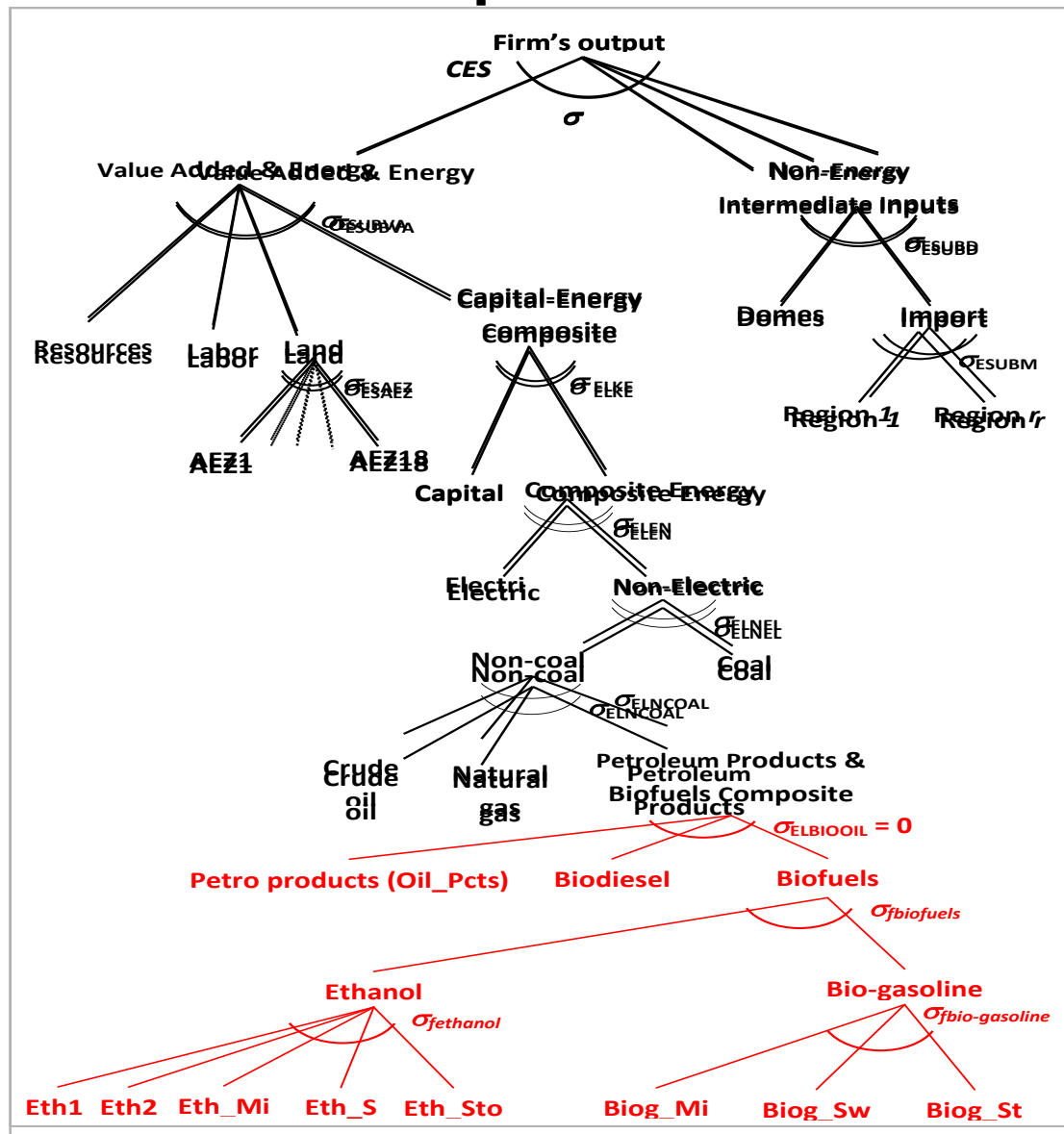
Petroleum products &
Biofuels composite

Petro products
(Oil_Pcts)

First and Second Generations of Biofuels
(G-Eth, S-Eth, Biod, M-Eth, S-Eth, Sto-Eth,
M-Biog, S-Biog, Sto-Biog)



Modifications in production functions



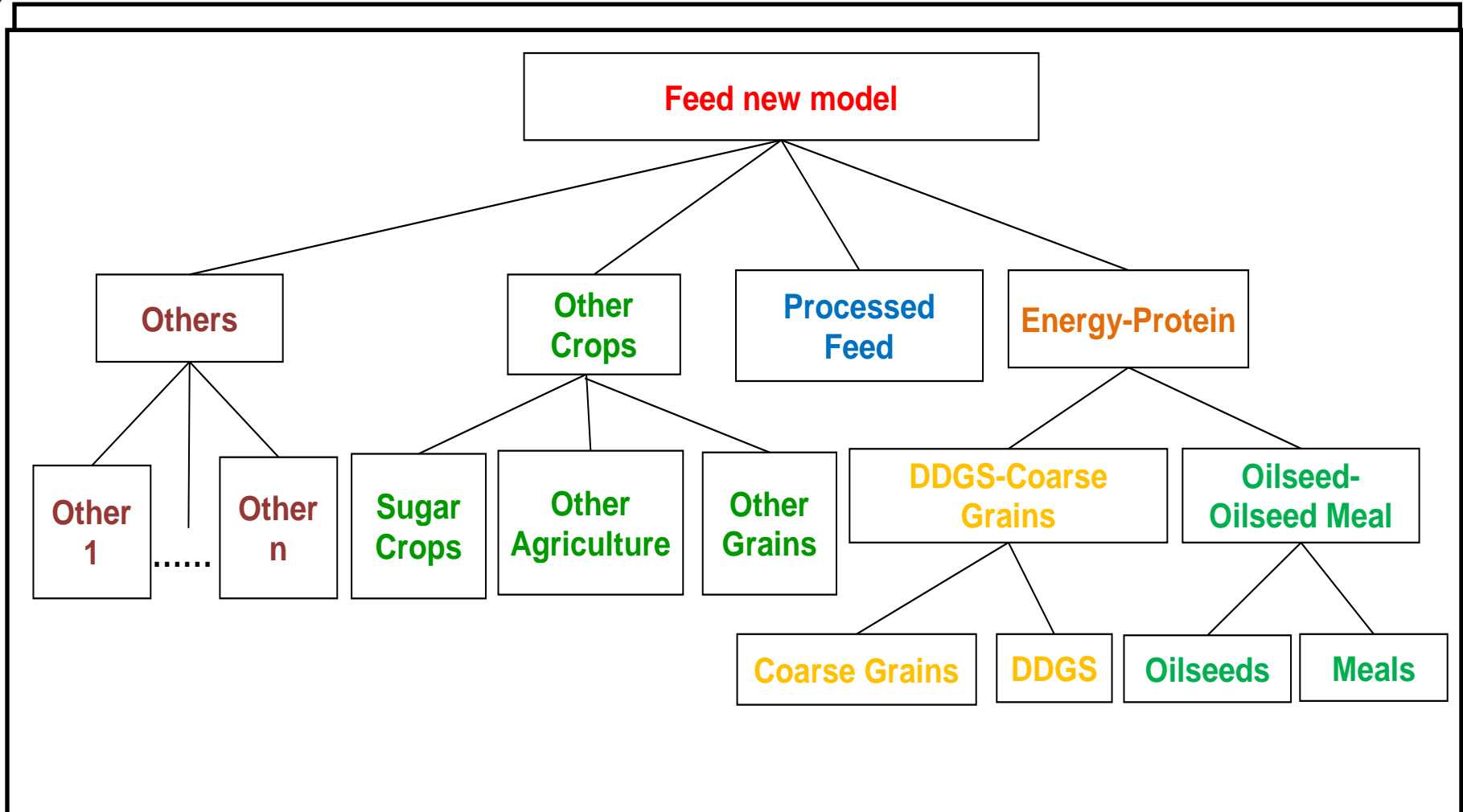
Other model modifications

- Updated **energy** elasticities,
- Improved treatment of grains, DDGS, and oilseed meals in **animal feed** module,
- **Separation** of soybean, palm, and rapeseed from other oilseeds,
- **Separation** of soybean, palm, and rapeseed vegetable oils from other vegetable oils and fats,
- **Separation** of biodiesel production by soybean, palm, and rapeseed,
- **Substitution** among alternative vegetable oils.
- Incorporate **cropland pasture** for US and Brazil and CRP for US.

Other model modifications

- Endogenous yield **adjustment** for cropland pasture,
- Greater **flexibility** in cropland **switching**
- **Tuning** regional land transformation parameters according to **recent** observations,
- **New** land **cover** nesting structure with forest separated from cropland and pasture.
- **Corn oil** is now separated in the ethanol production process.

A nesting feed demand is introduced into GTAP

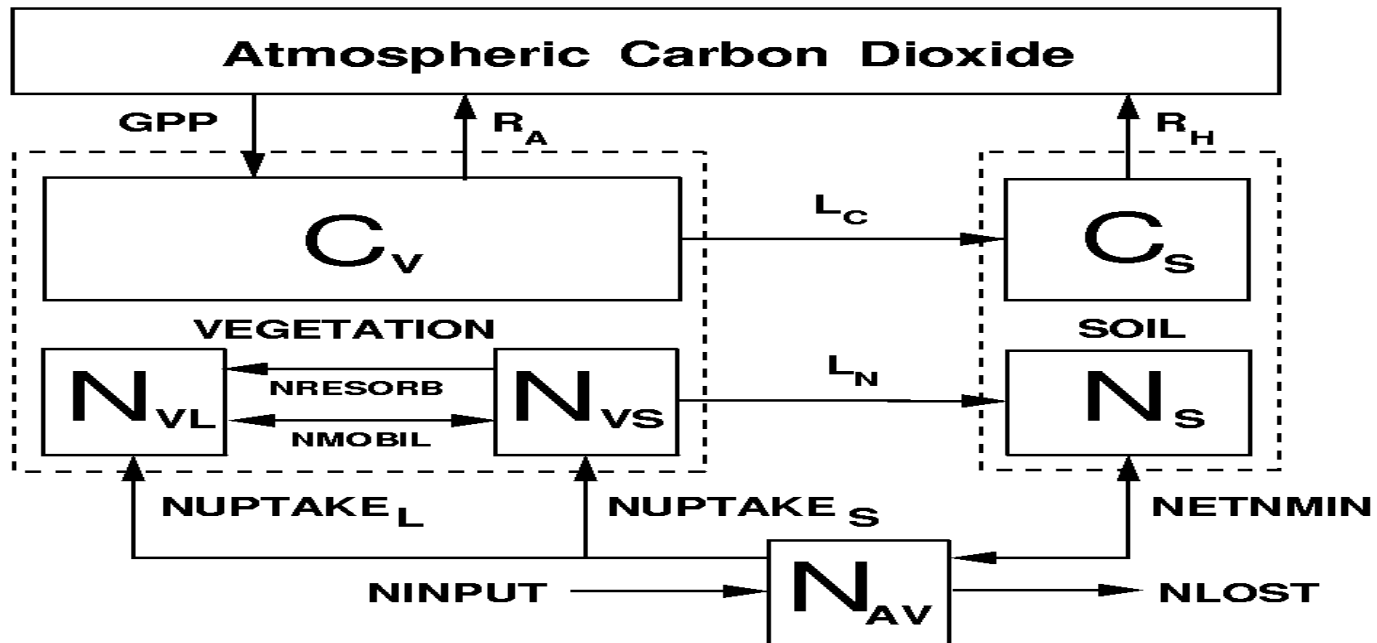


Modification in extensive margin

- **Moving** into forest and pastureland:
 - We measure productivity of **new** cropland versus **existing** cropland with a parameter called **ETA**,
 - In our earlier work, we used **ETA=0.66** for **all** regions across the world (based on Field, Campbell, Lobell, 2007)
- We developed a new set of regional ETAs by AEZ using a process-based biogeochemistry model (Terrestrial Ecosystem Model (**TEM**)) along with spatially referenced information on climate, elevation, soils, and vegetation land use data.

Using TEM to estimate regional extensive margins

- In **TEM**, the net ecosystem exchange of CO_2 between the land ecosystems and atmosphere is calculated (known as Net Primary Product - **NPP**)

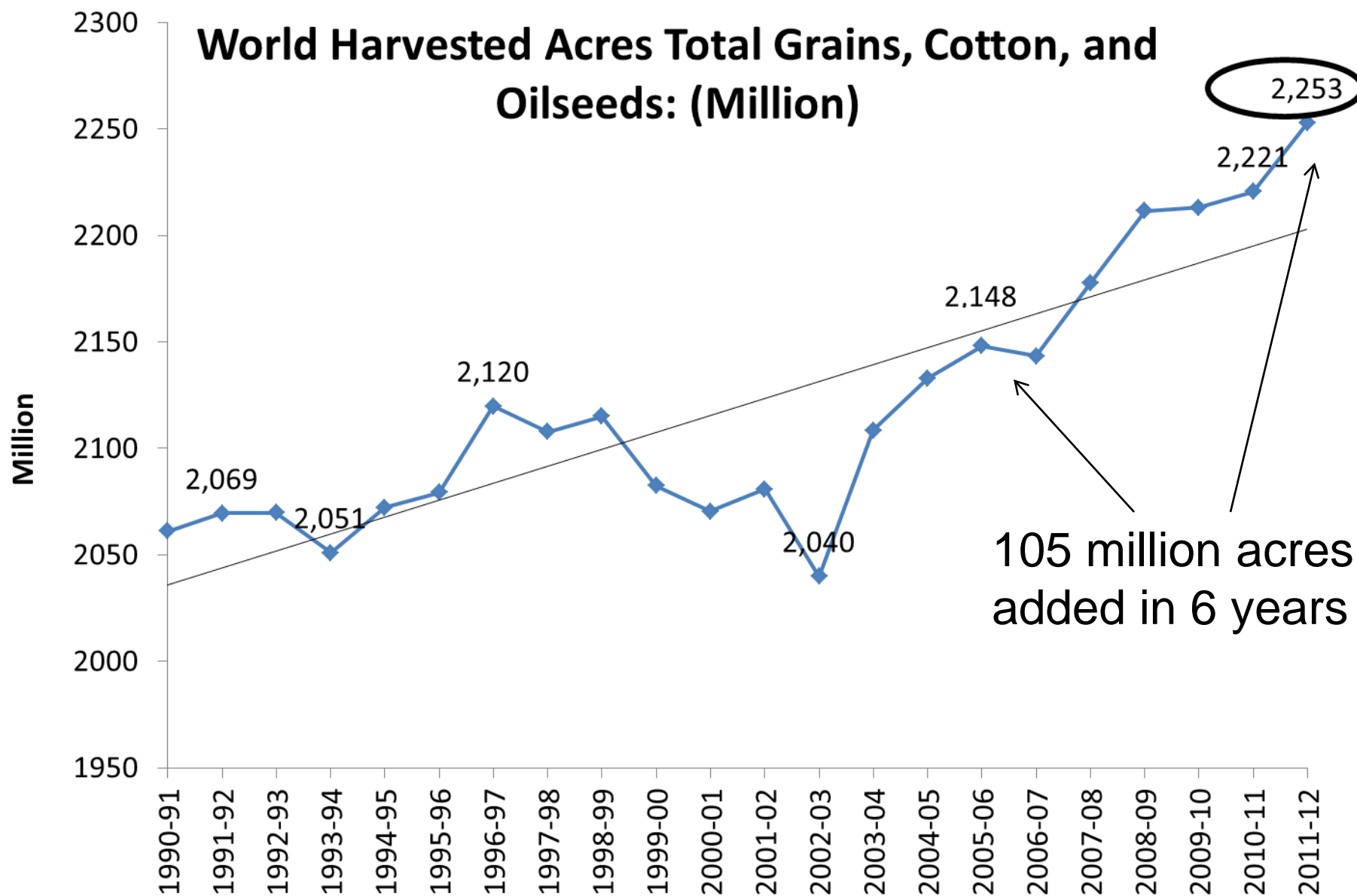


The Terrestrial Ecosystem Model (TEM)

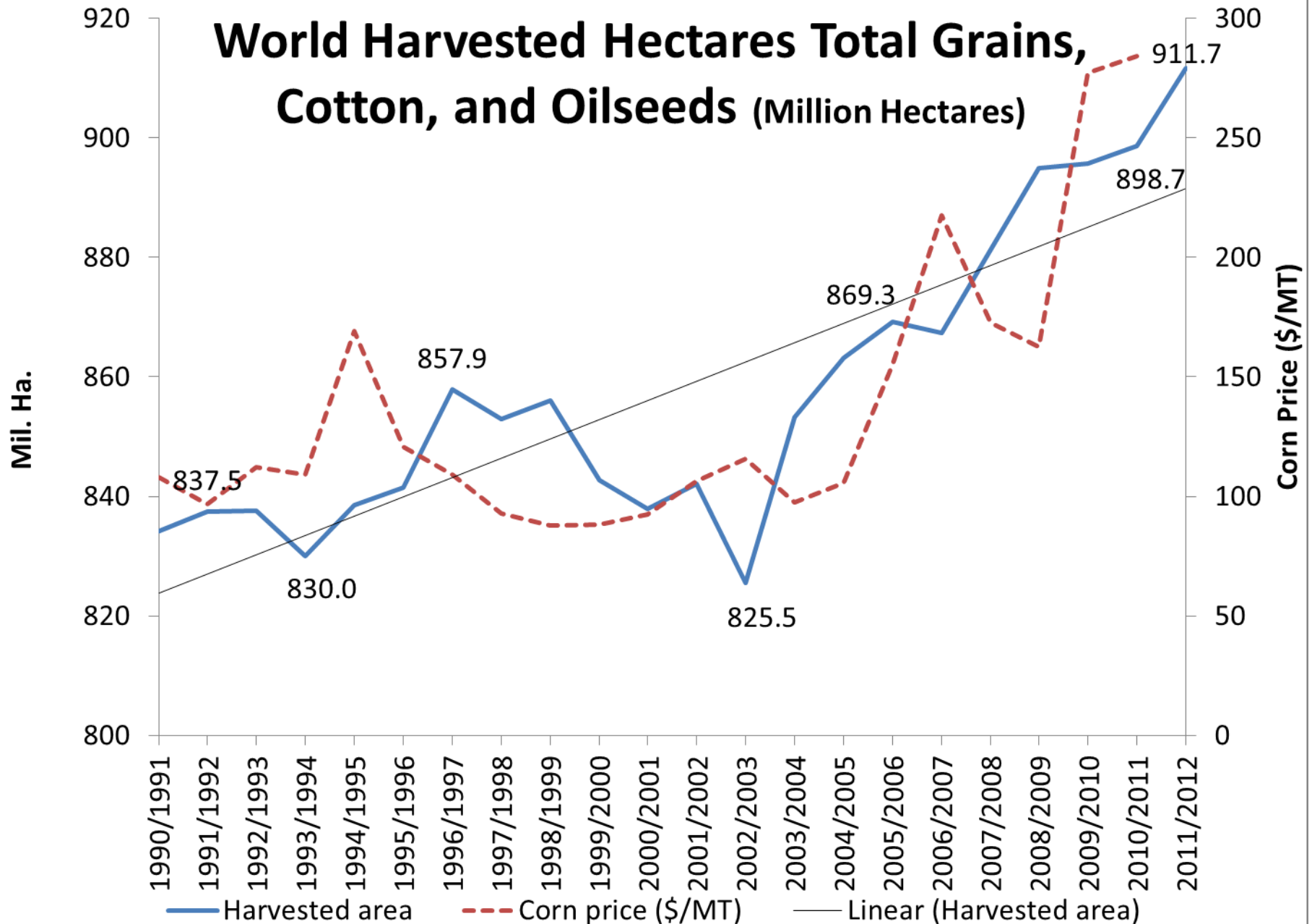
Using TEM to estimate regional extensive margins

- Parameters in TEM may be specific to different vegetation types. We assigned parameters for two generic crops: **C3** and **C4**.
- To run TEM, data on atmosphere, vegetation, soil texture, and elevation at $0.5^{\circ} \times 0.5^{\circ}$ resolution from 1900 to 2000 is used.
- We dropped lands **not suitable** for crop production.
- To derive regional ETAs we compared **NPP-C4** of areas with **natural** cover with **NPP-C4** of **cropland** areas at AEZ level.
- **ETA** values obtained from **C4** and **C3** were almost **identical**.
- Estimated ETA values ranged from **0.42** to **1**.

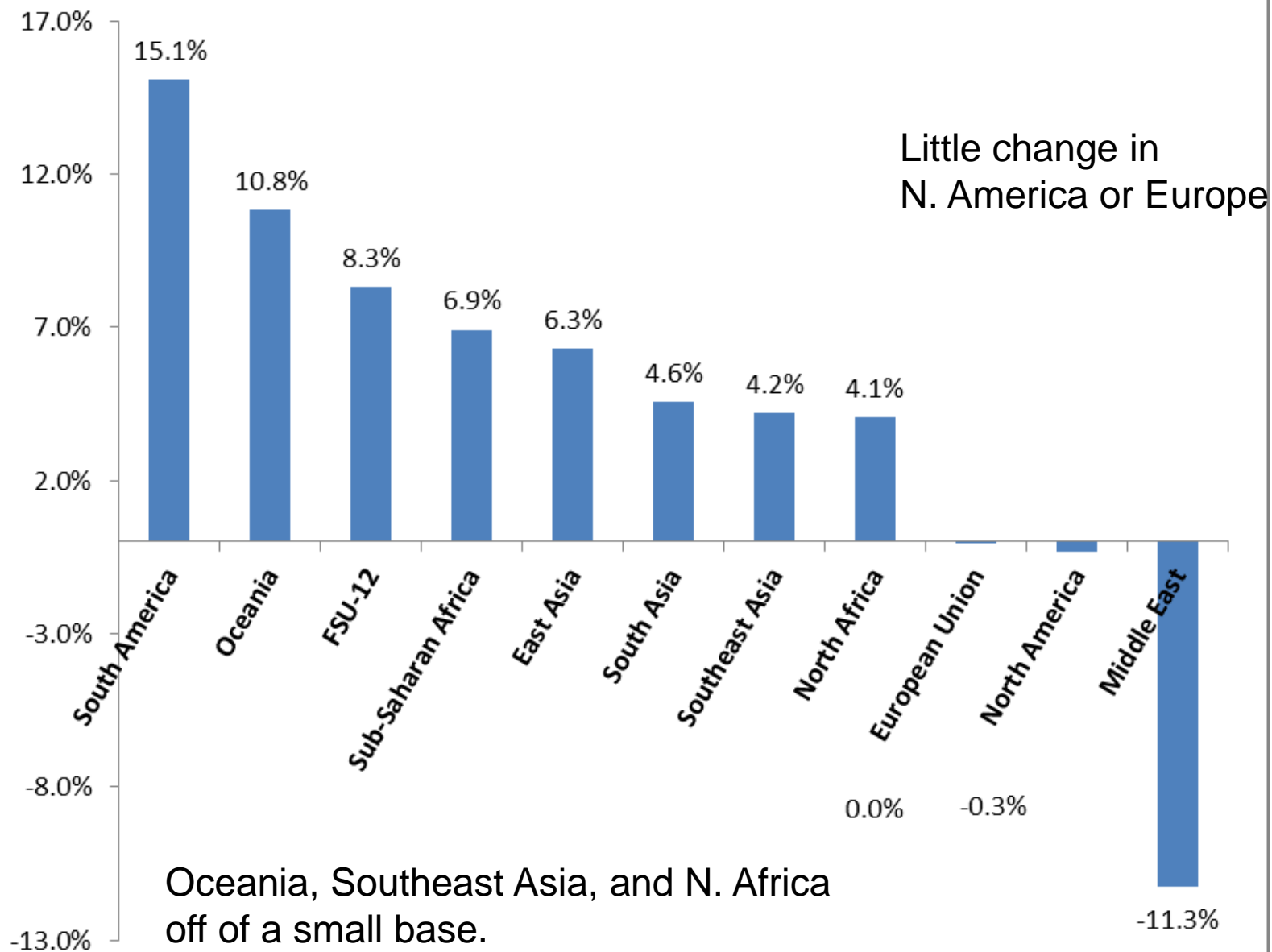
World Harvested Acres Total Grains, Cotton, and Oilseeds: (Million)



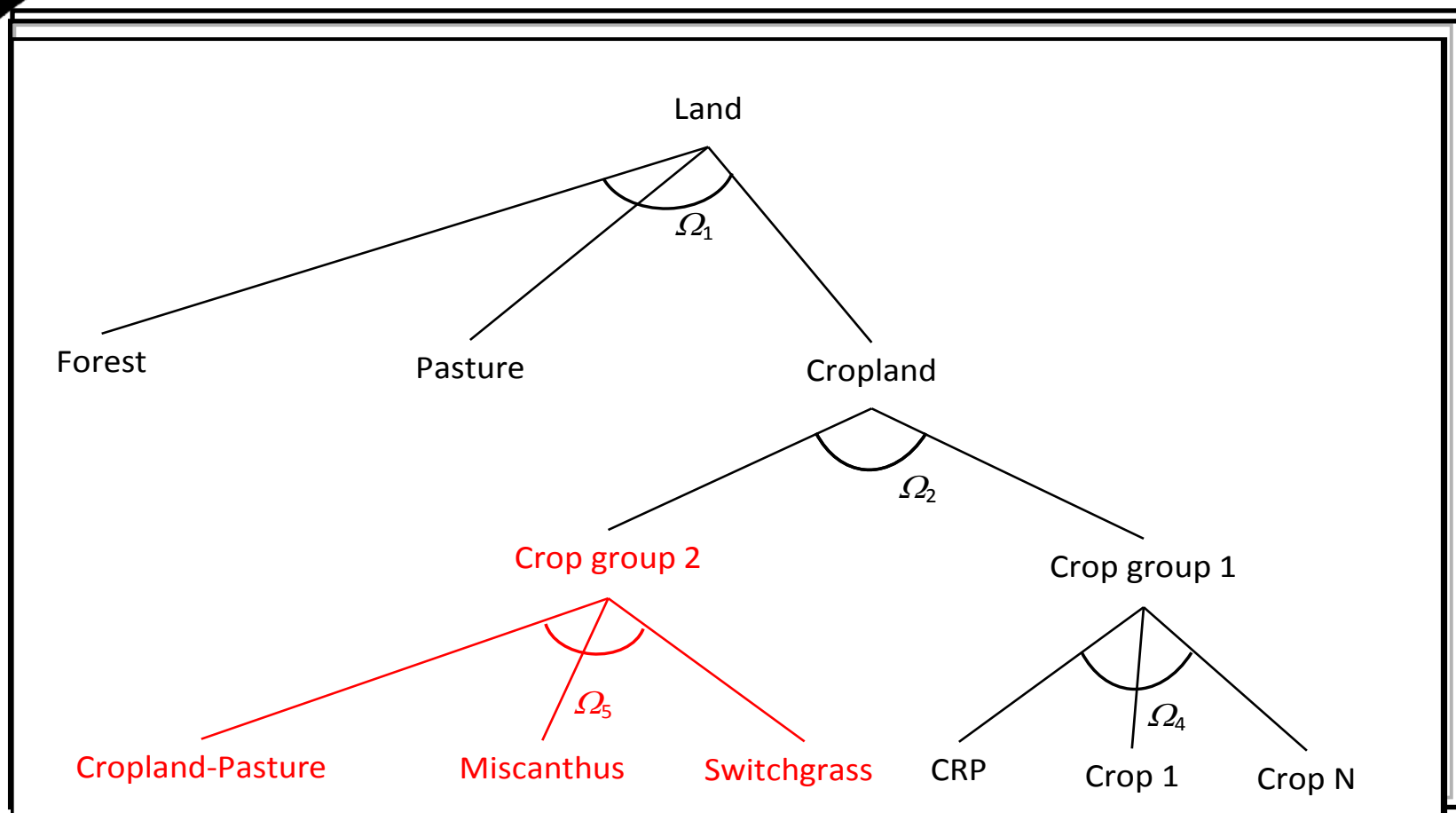
World Harvested Hectares Total Grains, Cotton, and Oilseeds (Million Hectares)



Change in Area Harvested in 13 major World crops 2011/12 vs. 2005/06
(1,000 hectares)



Land supply in GTAP



$\Omega_{1,1}$, $\Omega_{1,2}$, and Ω_2 are tuned according to actual observations over 2000-2012 (Faheripour and Tyner, 2013)

Ω_4 and Ω_5 are GTAP Base model with dedicated crops

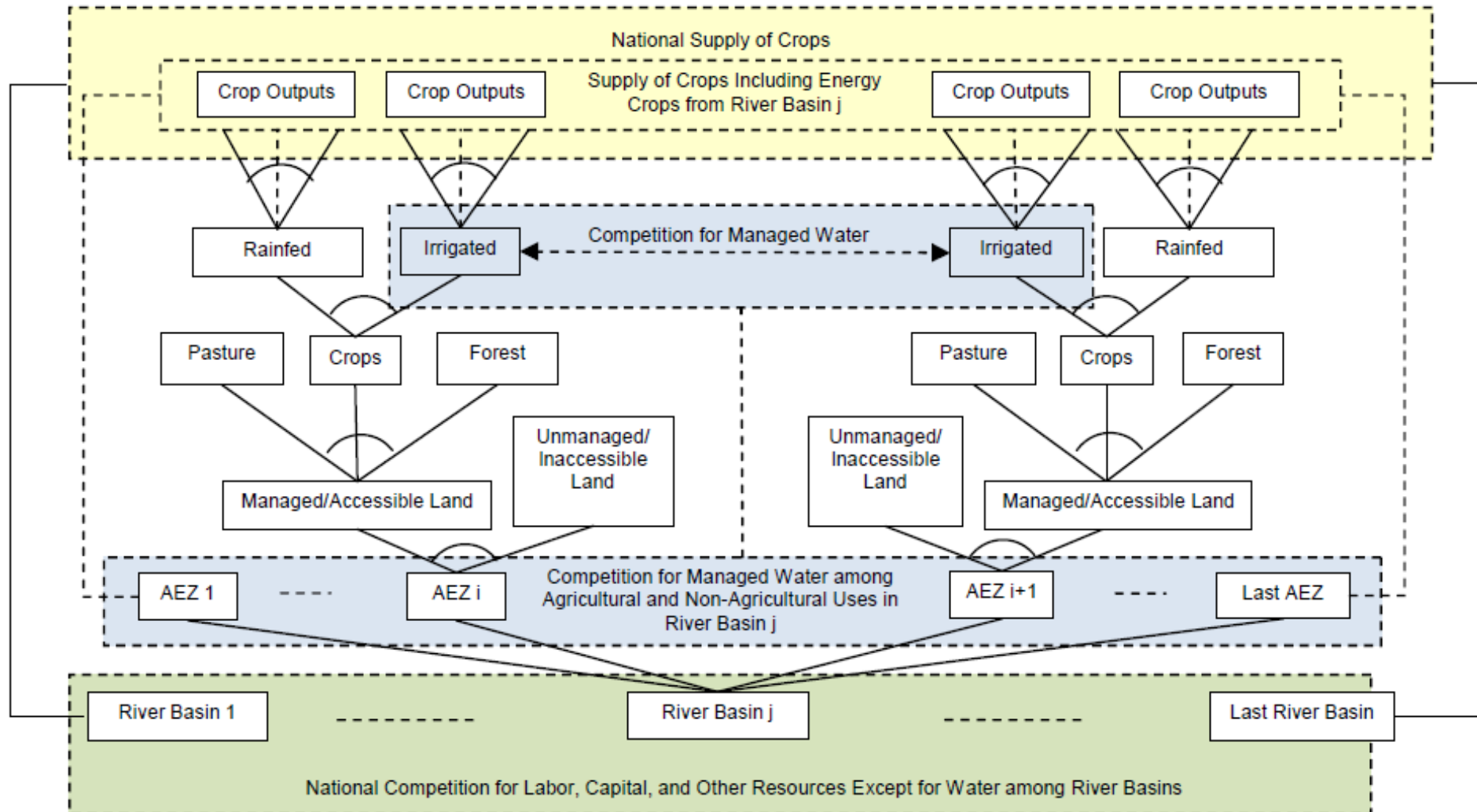
Other issues

- We now have **cellulosic** biofuels from corn stover, miscanthus, and switchgrass and the associated processing industries.
- Cellulosic biofuels are simulated with **external shocks** for each type of feedstock and biofuel (ethanol or gasoline type fuel).
- In the future, we will be exploring possible changes in the crop nesting structure to better reflect the fact that area in some crops remains relatively stable while others vary significantly.

Introducing rainfed and irrigated crops and water supply into GTAP data base

- Portman, Siebert, and Döll (2010) gridded data set is used to **split** GTAP **crop** industries into **irrigated** and **rainfed** crop categories,
- Siebert and Döll (2010) gridded data set is used to introduce **water** used in **irrigated** crop industries into GTAP database,
- Land cover, harvested area, crop production, and water used for irrigation is introduced into version 6 GTAP data base by **18 AEZs** and **20 river basins** by region.

GTAP modeling framework with water resources



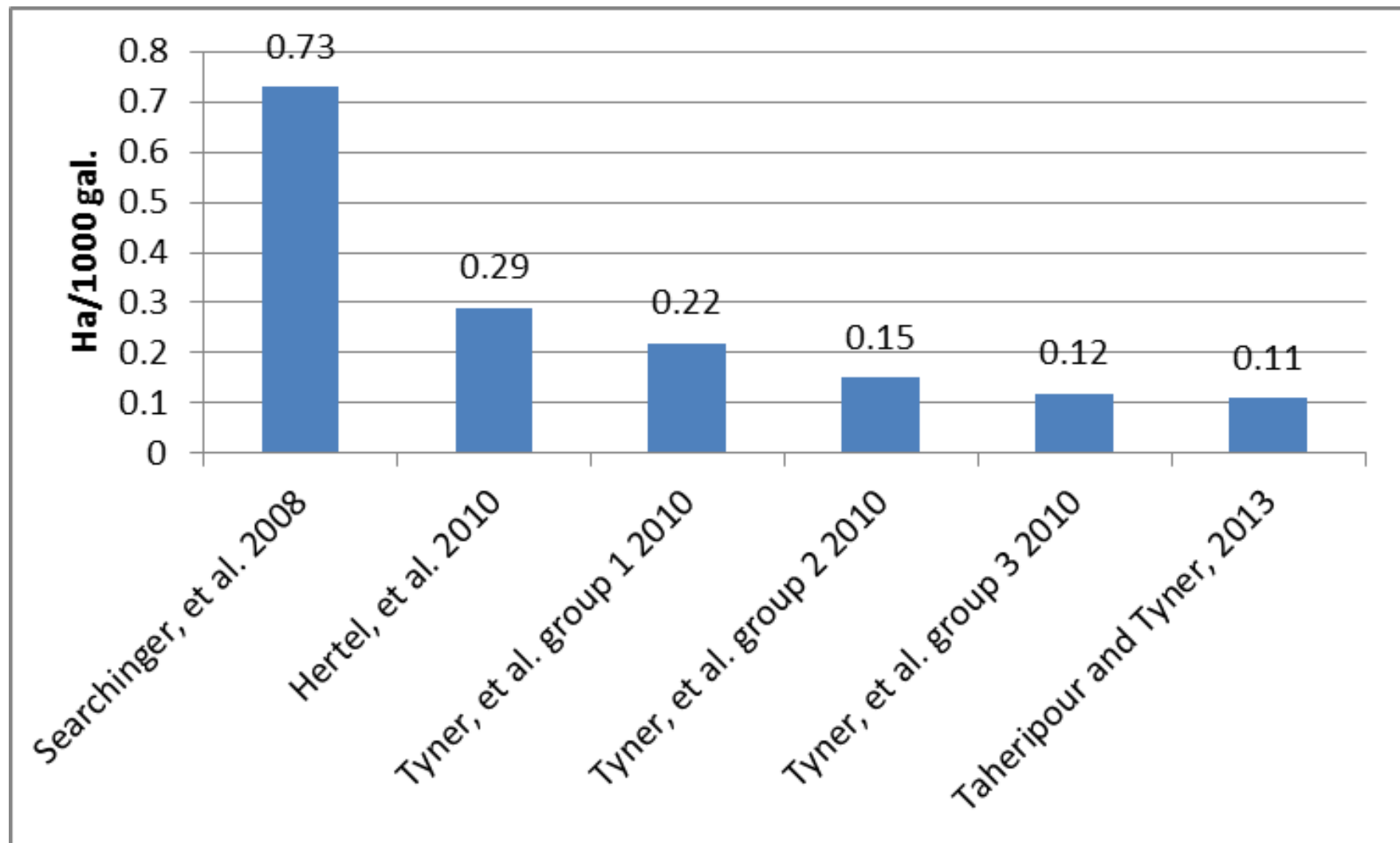
Other issues

- In recent work, we have shown that the **approach used** to **pay** for biofuel **subsidies** or mandates is important in **measuring** welfare and land use impacts.
- For the **US**, the **higher** crop prices, partly because of biofuels, mean that **output based agricultural subsidies** are no longer paid, and need to be adjusted in GTAP.
- Adjustments make **significant changes** in the GTAP simulation results, in particular for **crop prices and land use**.

Links to other models

- We have used GTAP **land supply** curves generated with biofuels shocks to provide land supply for the **MARKAL** model.
- MARKAL is a bottom-up **energy** sector model, and we modified the biofuels part to better reflect supply reality.

Evolution of land use results



Relevant findings

- To accommodate the demand for biofuels, land can come from crop switching or from pasture and forest conversion. Results suggest **switching** is important.
- There is uncertainty in induced land use change, but also there is considerable **uncertainty** in the land use **emission factors** used to calculate emission from the land use change estimates.

Thank you!
Questions and Comments

For more information:

<http://www.agecon.purdue.edu>

Click on faculty directory and then Tyner