California Environmental Protection Agency

Air Resources Board

Low Carbon Fuel Standard Re-Adoption Indirect Land Use Change (iLUC) Analysis

September 29, 2014

Agenda

- Previous iLUC analysis
- Updates to GTAP model
- Draft Results
  - Scenario analysis
  - Uncertainty analysis
- Next Steps

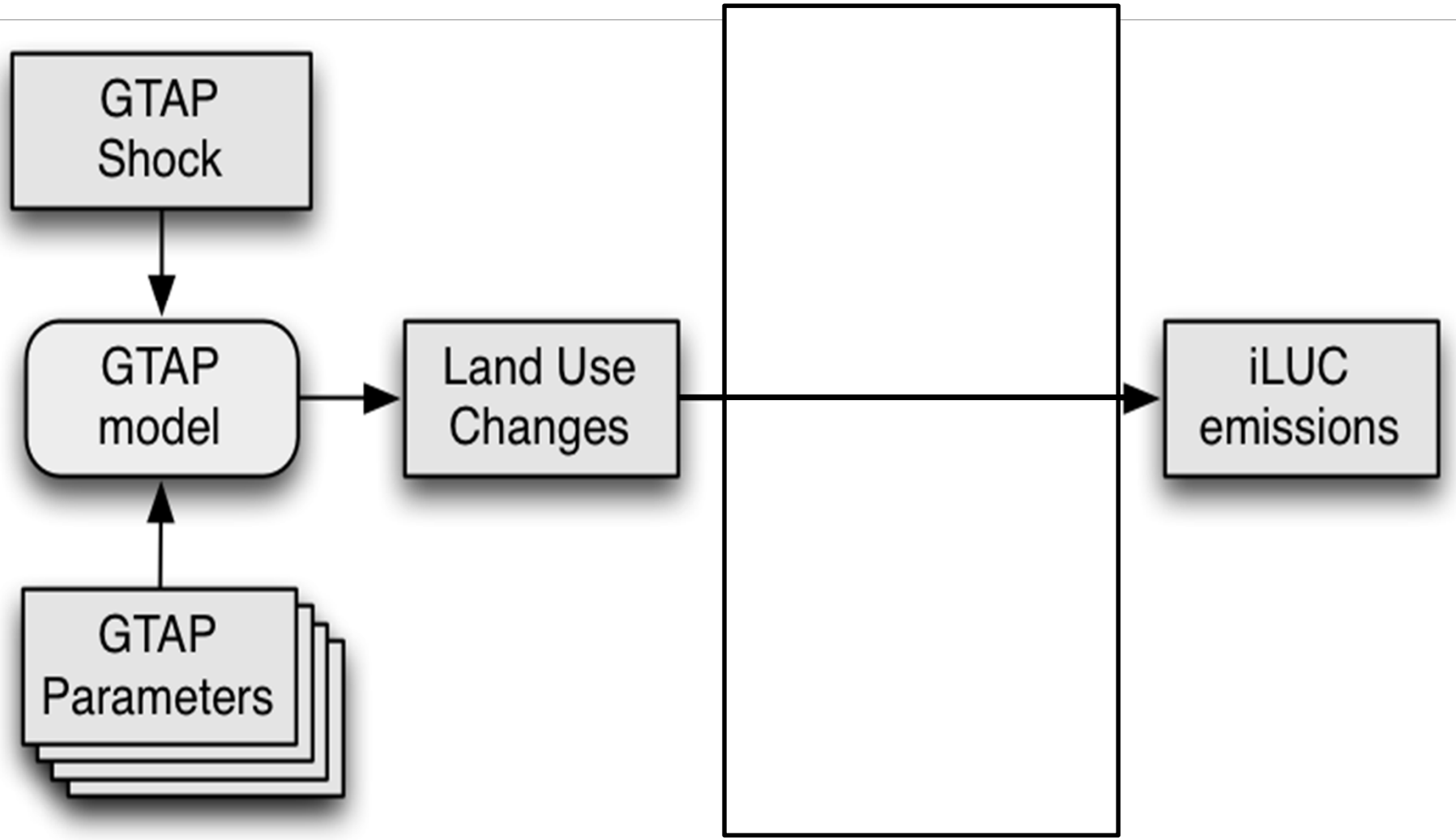
iLUC Values: 2009-2014

	Board Approved (2009-2010)	**March 2014 (draft)**
Corn Ethanol	30.0	23.2
Sugarcane Ethanol	46.0	26.5
Soy Biodiesel	62.0	30.2
Canola Biodiesel	n/a	41.6

iLUC: Current Work
Carbon Emissions and GTAP

GTAP Integration with Carbon Emissions

(iLUC Estimation Methodology)



Agro-Ecological Zone - Emissions Factor (AEZ-EF) Model

(developed by UCB, UCD and U. of Wisconsin)

AEZ-EF: Update

- Staff reviewed feedback on AEZ-EF model
- No changes made to the March version of the AEZ-EF model
- Minor changes will be made in October 2014
- Impacts on iLUC expected to be negligible
- Updated model will be made available when changes have been implemented

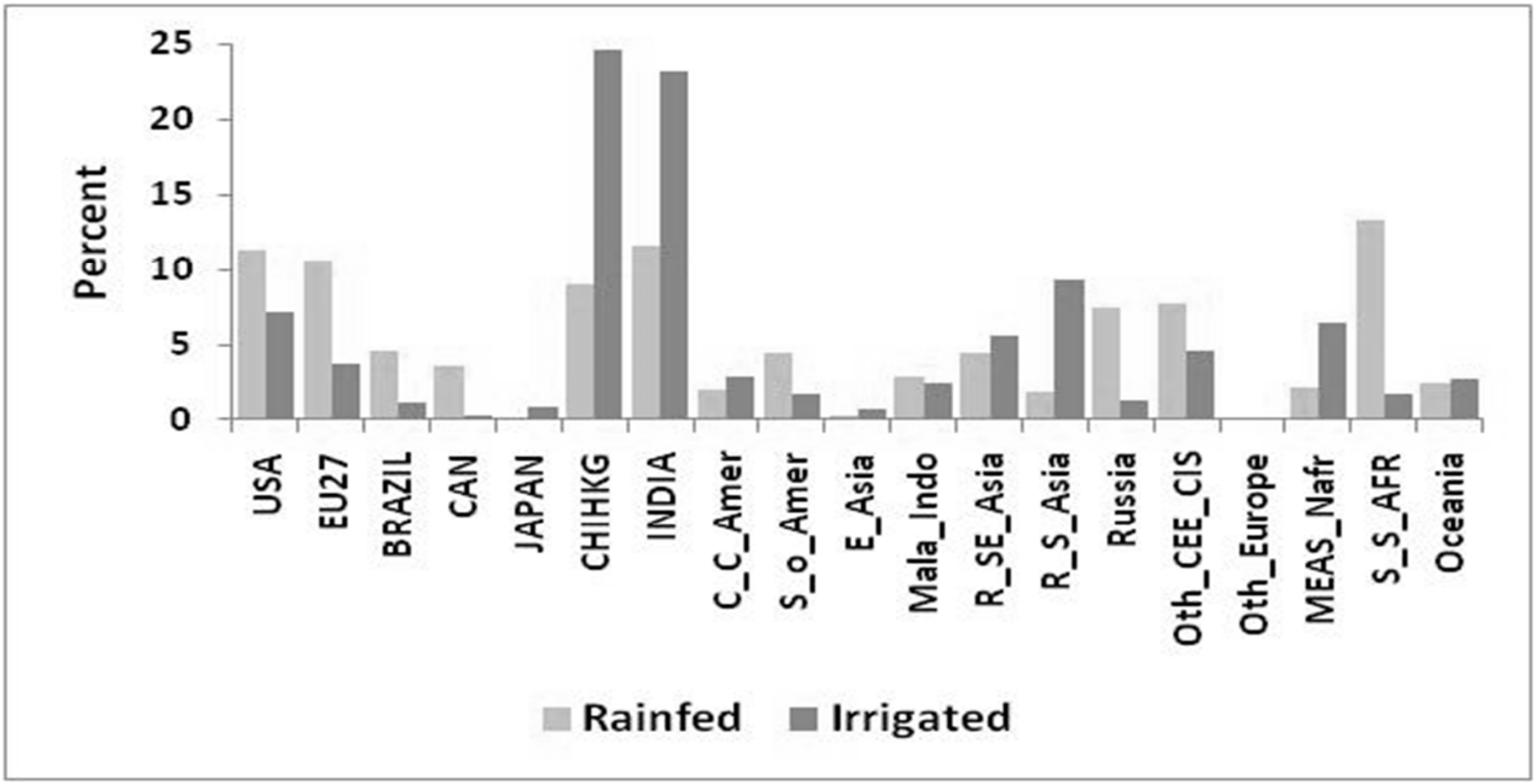
GTAP: Current Work

GTAP: Updates since March 11

- Model
  - Incorporated irrigated/rain-fed cropland category within the GTAP model
  - Used water scarcity information from World Resources Institute (WRI) for use with GTAP regions/AEZs
  - Included option of updated land transformation structure
- Parameter
  - Included a disaggregated Yield Price Elasticity (YPE) option based on crop and region

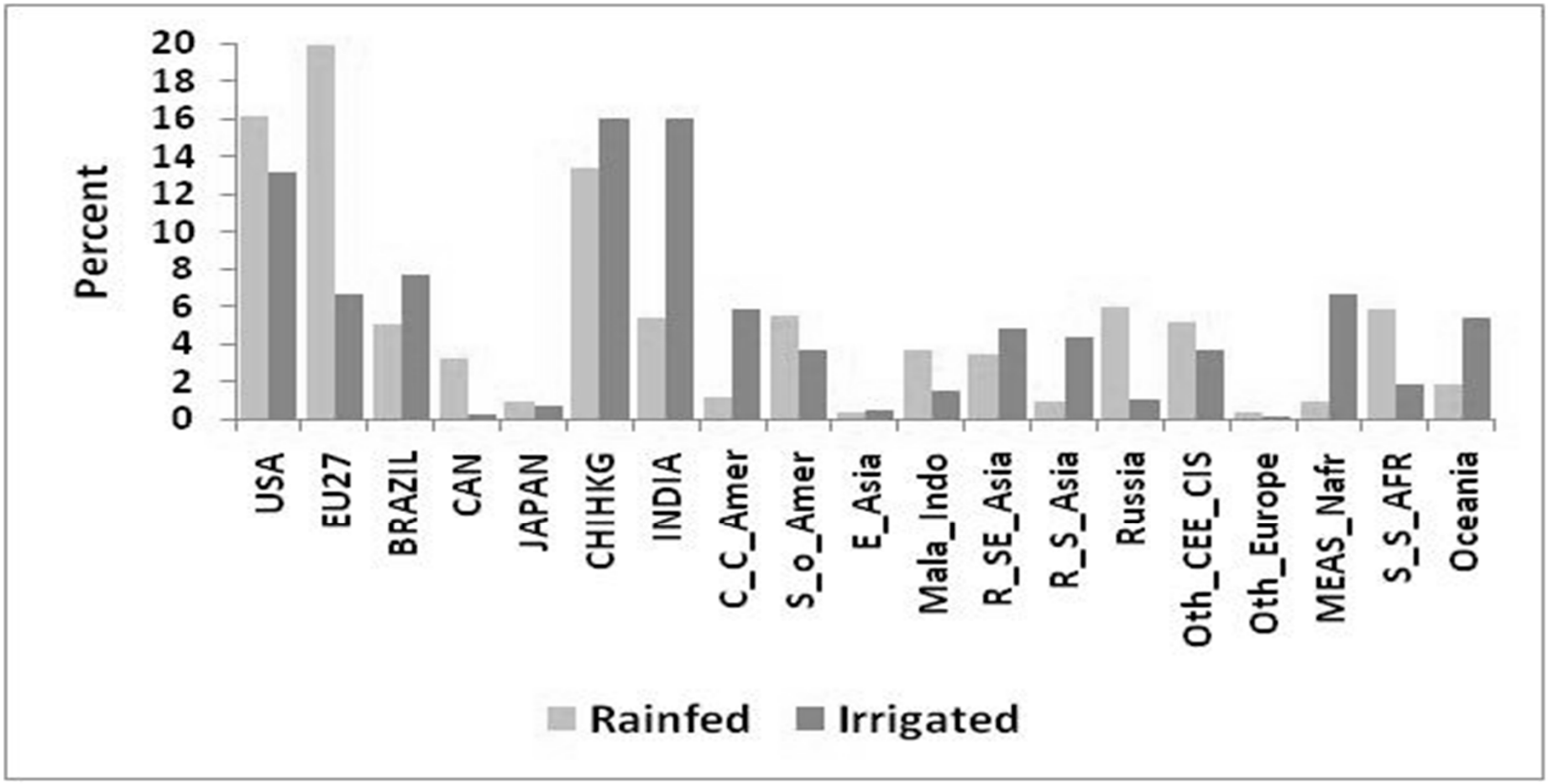
GTAP: Irrigated/Rain-Fed Cropland

GTAP: Global Distribution of Harvested Area by Irrigated/Rain-fed



Irrigated area accounts for about 20% of global cropland cover (adapted from Taheripour, Hertel, and Liu, 2011)

GTAP: Global Distribution of Crop Production by Irrigated/Rain-fed



Irrigated production accounts for more than 40% of total crop production (adapted from Taheripour, Hertel, and Liu, 2011)

GTAP: Why did we Consider Including Irrigated/Rain-Fed Cropland?

- Irrigated cropland typically has higher yield compared to rained cropland in a given AEZ/Region
- If cropland expansion occurs in irrigated land, higher yields translate to smaller land requirements
- Availability of water for irrigation may be a constraint that limits expansion into irrigated land*

* Taheripour, Hertel, Liu, (2013)

GTAP: Inclusion of Irrigation into the Model

- Earlier versions used an average of irrigated and rain-fed cropland
- Expansion of cropland did not differentiate between irrigated (higher yields) or rain-fed (comparatively lower yields) areas
- Model used for the analysis presented today differentiates irrigated and rain-fed cropland*
- Current version modified cropland transformation tree structure to differentiate between irrigated and rain-fed cropland

* Taheripour, Hertel, Liu, (2013)

GTAP: Water Constrained Regions/AEZs

AEZ →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Region ↓																		
1 USA							1	1	1				1	1				
2 EU27									1									
3 BRAZIL																		
4 CAN							1	1										
5 JAPAN									1			1						
6 CHIHKG							1	1	1	1			1					
7 INDIA	1	1	1				1	1	1	1					1	1		
8 C_C_Amer	1	1					1	1	1	1	1							
9 S_o_Amer	1	1					1	1	1									
10 E_Asia											1							
11 Mala_Indo				1	1													
12 R_SE_Asia																		
13 R_S_Asia	1		1				1	1	1	1			1					
14 Russia																		
15 Oth_CEE_CIS							1	1					1	1				
16 Oth_Europe																		
17 MEAS_NAfr			1	1			1	1	1	1								
18 S_S_AFR								1										
19 Oceania	1							1	1	1	1							

1 indicates water constrained

GTAP: Impacts related to Irrigated/Rain-Fed Cropland

- Conducted scenario runs with water constrained regions
- Inclusion of irrigated/rain-fed cropland impacts on iLUC values determined to be small

Elasticity of Land Transformation (ETL)
(a) Land Supply Structure
(b) ETL Values Used

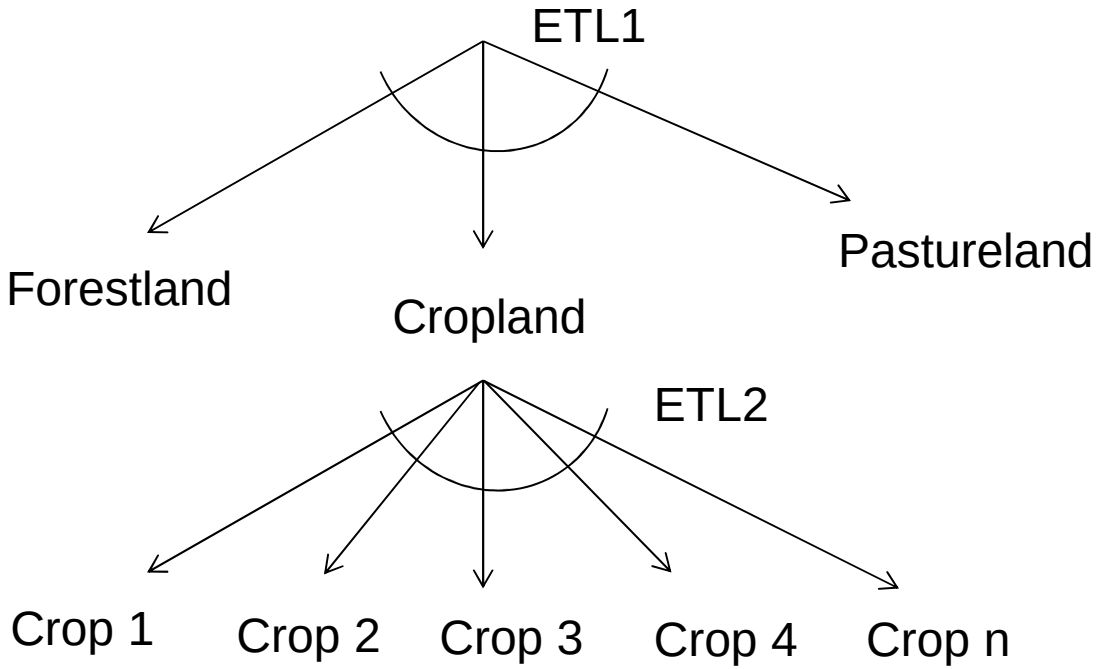
GTAP: Land Supply Structure

- GTAP predicts land conversion from one type of land cover to another (e.g., forest-crop, pasture-crop, etc.)
- GTAP uses Land Transformation Elasticity (ETL) to model land conversion
- The value of the ETL parameter governs the ease (or difficulty) of land conversion

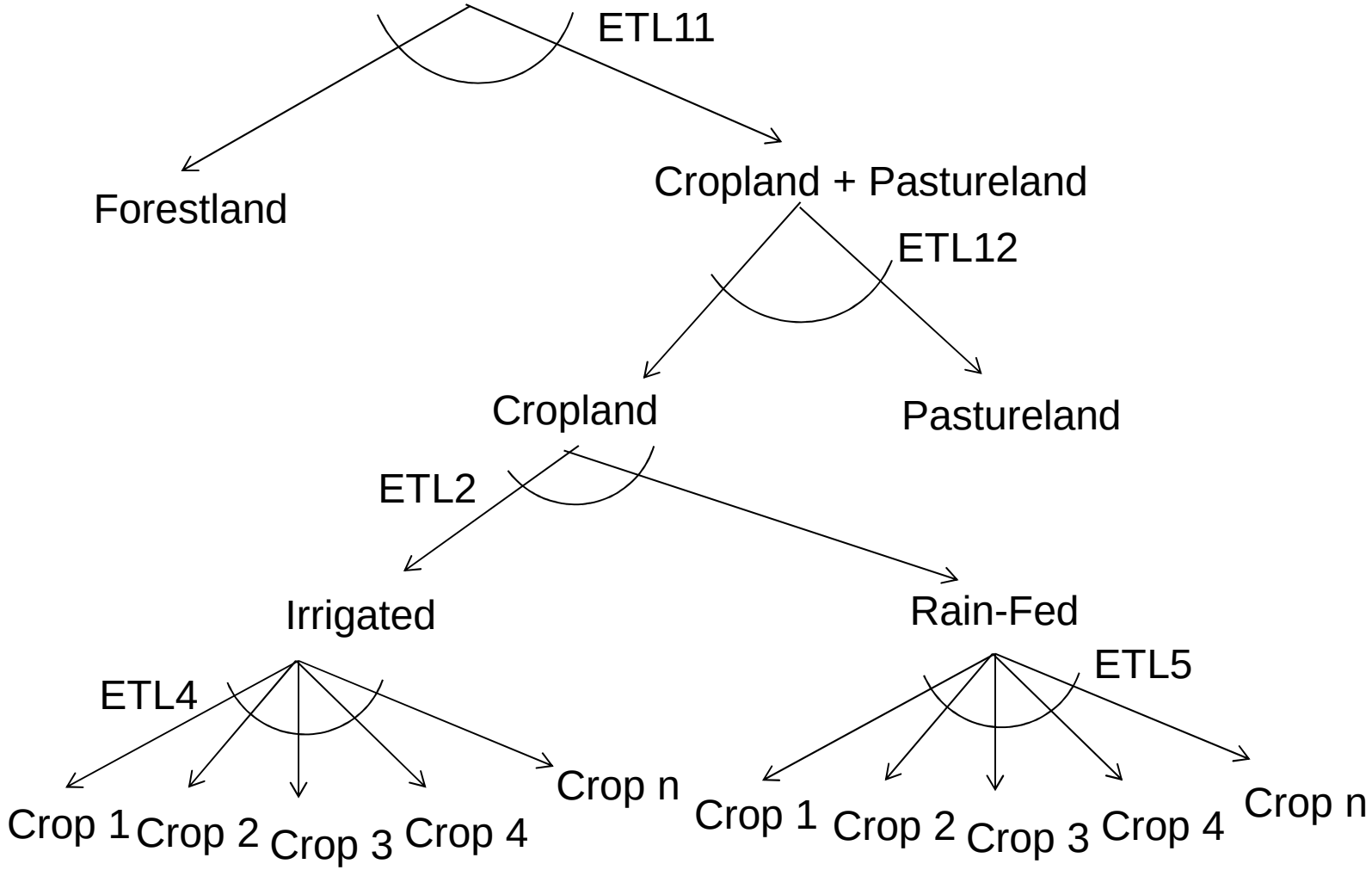
GTAP: ETL

- The elasticity of land transformation is intended to reflect biophysical land heterogeneity within an AEZ, region-specific infrastructure, socioeconomic factors, ownership of land, costs of conversion, managerial inertia, unmeasured benefits from crop rotation, etc.
- There is limited econometric estimate of these elasticities due to lack of sufficient data; values used mostly based on assumptions

GTAP: Old Structure (March 2014)



GTAP: New Structure (Current)



GTAP: ETL values for Scenarios

- There is no consensus on the appropriate values to be used for the different ETLs
- Staff has therefore considered two different approaches using two sets of ETL values for scenario runs
  - Approach A: ETL11 = ETL12
  - Approach B: Separate ETL11 and ETL12 values
- Results presented today reflect the two approaches (preliminary)

Approach A: ETL11 = ETL12

GTAP Region	ETL11	ETL12	ETL2	GTAP Region	ETL11	ETL12	ETL2
USA	-0.02	-0.02	-0.75	R_SE_Asia	-0.3	-0.3	-0.50
EU27	-0.02	-0.02	-0.75	R_S_Asia	-0.1	-0.1	-0.75
BRAZIL	-0.2	-0.2	-0.75	Russia	-0.02	-0.02	-0.75
CANADA	-0.02	-0.02	-0.25	Oth_CEE_CIS	-0.02	-0.02	-0.75
JAPAN	-0.2	-0.2	-0.50	Oth_Europe	-0.02	-0.02	-0.25
CHIHK	-0.2	-0.2	-0.25	MEAS_NAfr	-0.02	-0.02	-0.25
INDIA	-0.1	-0.1	-0.25	S_S_AFR	-0.3	-0.3	-0.25
C_C_Amer	-0.02	-0.02	-0.25	Oceania	-0.02	-0.02	-0.25
S_o_Amer	-0.1	-0.1	-0.50				
E_Asia	-0.2	-0.2	-0.50				
Mala_Indo	-0.3	-0.3	-0.25				

Approach B: Separate ETL11 and ETL12

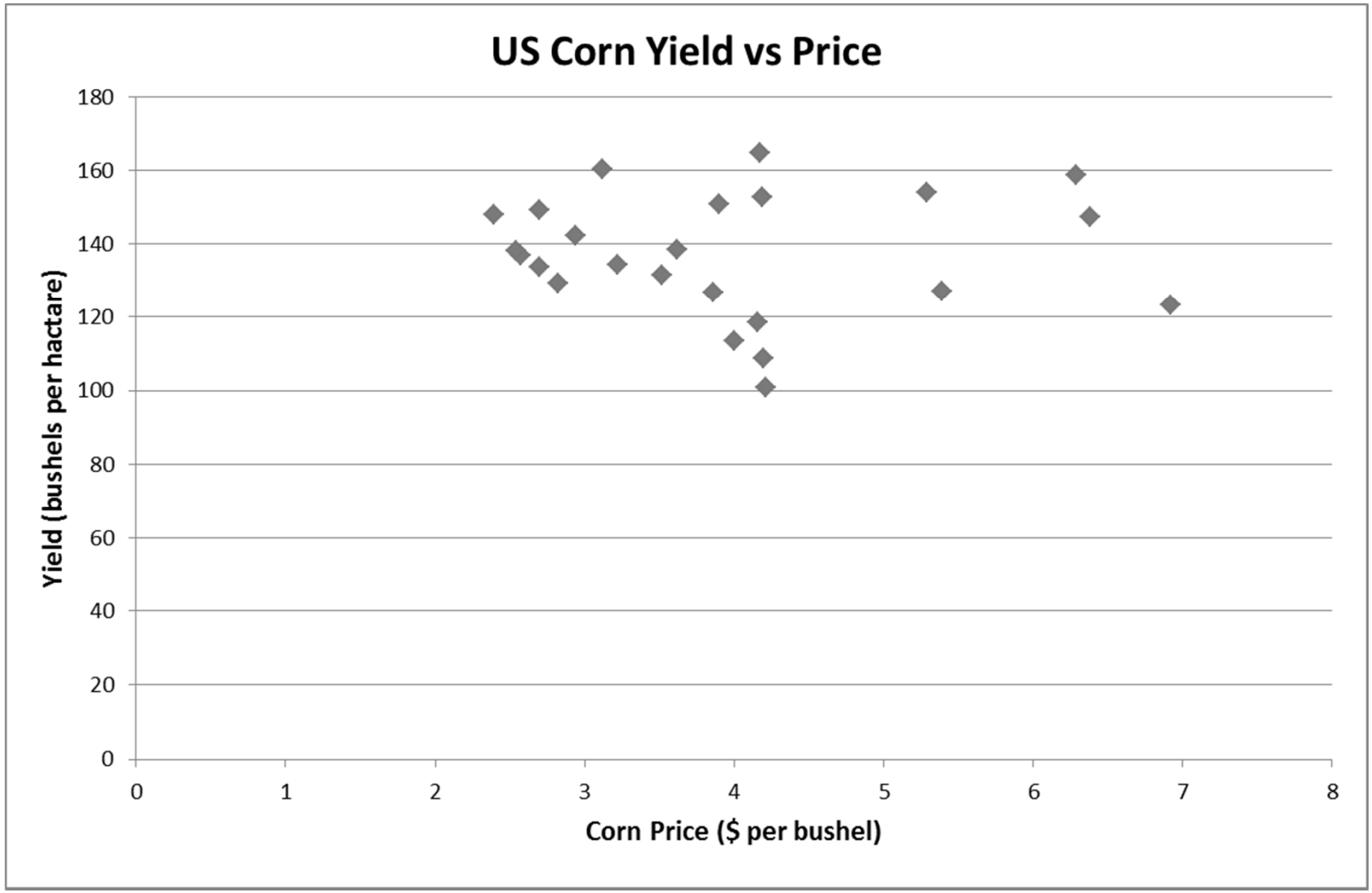
GTAP Region	ETL11	ETL12	ETL2	GTAP Region	ETL11	ETL12	ETL2
USA	-0.0182	-0.0218	-0.75	R_SE_Asia	-0.2727	-0.3273	-0.50
EU27	-0.0182	-0.0218	-0.75	R_S_Asia	-0.0909	-0.1091	-0.75
BRAZIL	-0.1905	-0.2095	-0.75	Russia	-0.0182	-0.0218	-0.75
CANADA	-0.0182	-0.0218	-0.25	Oth_CEE_CIS	-0.0182	-0.0218	-0.75
JAPAN	-0.1818	-0.2182	-0.50	Oth_Europe	-0.0182	-0.0218	-0.25
CHIHK	-0.1818	-0.2182	-0.25	MEAS_NAfr	-0.0182	-0.0218	-0.25
INDIA	-0.0909	-0.1091	-0.25	S_S_AFR	-0.2727	-0.3273	-0.25
C_C_Amer	-0.0182	-0.0218	-0.25	Oceania	-0.0182	-0.0218	-0.25
S_o_Amer	-0.0909	-0.1091	-0.50				
E_Asia	-0.1818	-0.2182	-0.50				
Mala_Indo	-0.2727	-0.3273	-0.25				

GTAP: Yield Price Elasticity (YPE)

GTAP: YPE

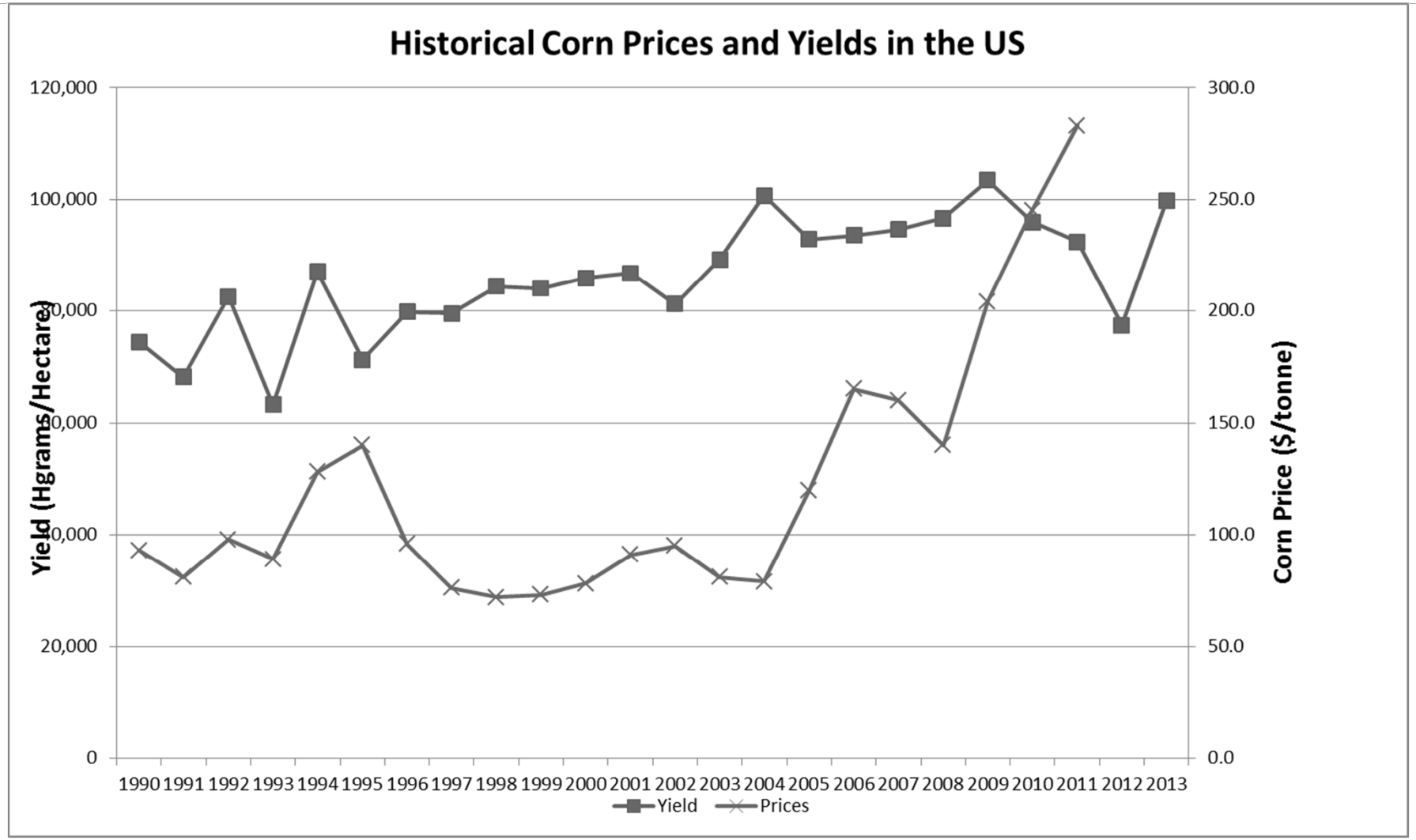
- March version allowed only a single value for YPE for all regions and crops
- Current version has the option of disaggregated YPE
- Capable of using a different value for YPE by crop and by region; this option is not exercised because availability of data to estimate YPE for all crops and regions is limited
- Current scenario runs use values between 0.05 and 0.35 as recommended by the Expert Working Group (EWG)
- Contracted with UC Davis to evaluate YPE using data from studies that have published YPE related information (work in progress)

Yield vs. Price for U. S. Corn



FAO data from 1990-2013

Historical Prices and Yields for U. S. Corn



FAO data

iLUC: Preliminary Results

iLUC: Scenario analysis

- 2009/2010 iLUC analysis: Average of 5 to 7 scenarios for each biofuel
- March 2014 iLUC analysis: 1440 scenarios for each biofuel
- Current analysis:
  - 30 scenario runs for each biofuel
  - Two separate sets of runs using Approach A and Approach B
  - Used variations of input values for YPE, ETA, and PAEL
  - Includes draft iLUC analysis for corn ethanol, sugarcane ethanol, soy biodiesel, canola biodiesel, and sorghum ethanol

iLUC: Values Used in Scenario Analysis

(30 runs)

Parameter/ Scenario	Description	Values
YPE	Yield Price elasticity	0.05, 0.125, 0.175, 0.25 and 0.35 **(5)**
PAEL	Cropland pasture elasticity	0.2 U. S. and 0.1 Brazil 0.4 U. S. and 0.2 Brazil **(2)**
ETA	Elasticity of crop yields with respect to area expansion	Baseline, 80%, and 120% of baseline **(3)**

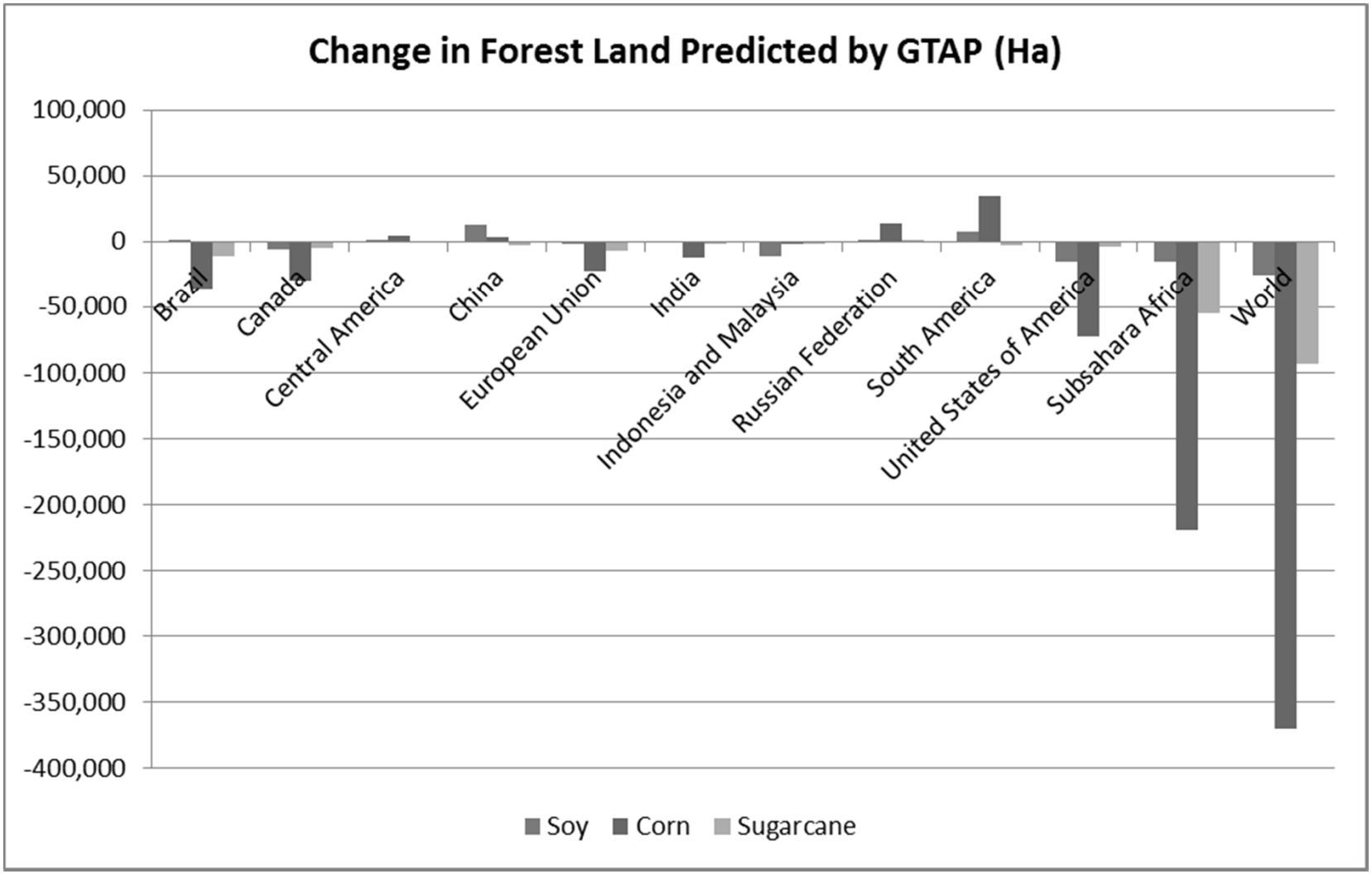
iLUC: Preliminary Results

Biofuel	2009 (g/MJ)	March 2014 Ave. (g/MJ)	Range of Values Appr. A (g/MJ)	Ave. of Appr. A (g/MJ)	Range of Values Appr. B (g/MJ)	Ave. of Appr. B (g/MJ
Corn Ethanol	30.0	23.2	13.6 – 42.0	**25.0**	11.5 – 37.0	**21.6**
Sugarcane Ethanol	46.0	26.5	16.2 – 44.1	**27.9**	10.7 – 36.3	**21.3**
Soy Biodiesel	62.0	30.2	16.6 – 51.4	**30.6**	14.2 – 45.6	**26.6**
Canola Biodiesel (US+EU)	n/a	41.6	21.2 – 68.9	**40.3**	18.2 – 61.1	**35.2**
Canola Biodiesel (US only)	n/a	n/a	6.1 – 21.0	**12.2**	5.0 – 18.5	**10.4**
Sorghum Ethanol	n/a	n/a	9.2 – 22.6	**14.6**	8.3 – 20.3	**13.0**

Comparison of GTAP Outputs with World Data

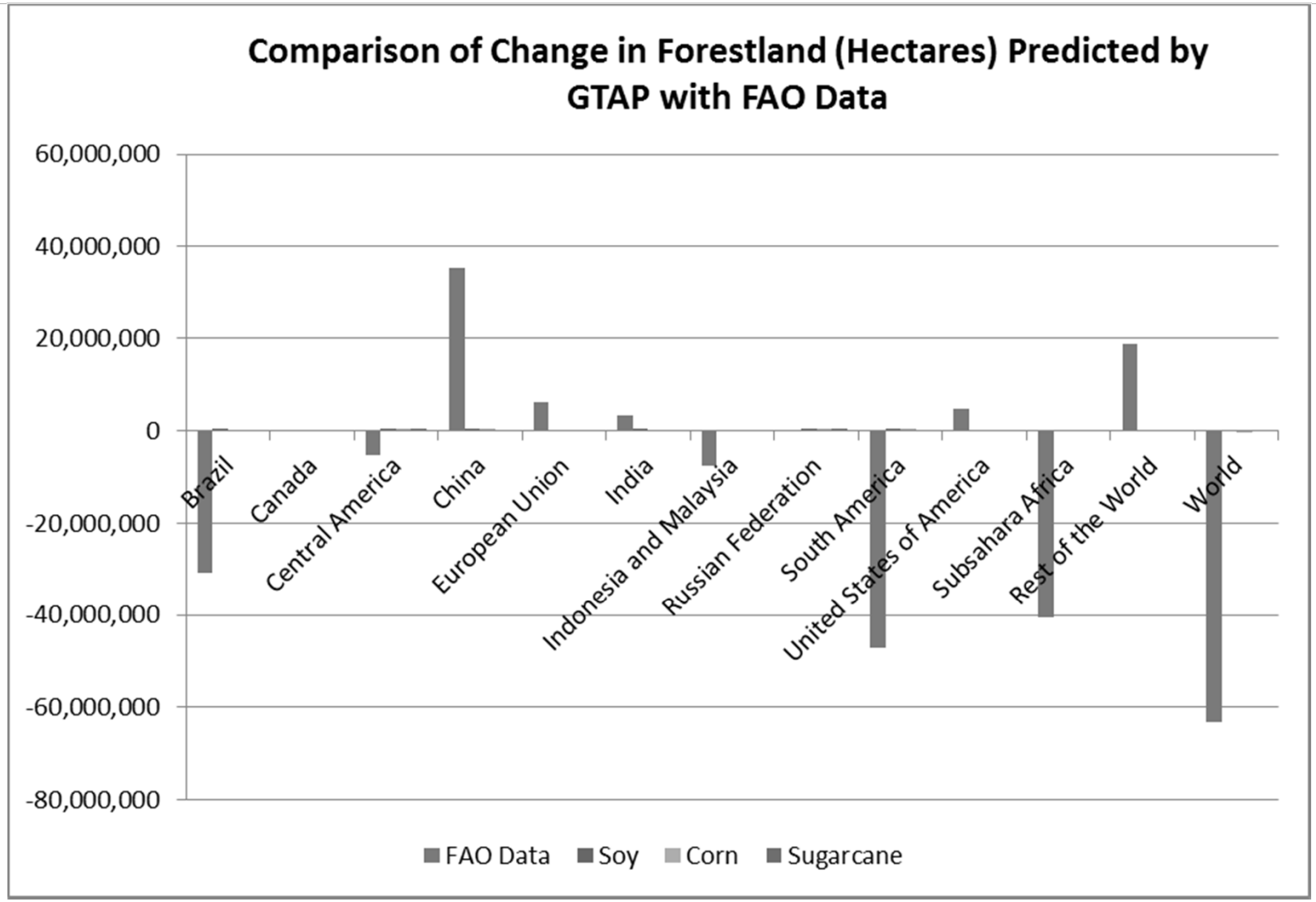
- World data on prices, yields, land changes, etc. reflects the effects of a large number of parameters: population changes, weather impacts, economic factors, etc.
- In contrast, GTAP predicted outputs reflect effects directly attributable to a single factor ('the shock')
- Direct comparison of global effects to GTAP predicted effects is not productive
- However, to respond to stakeholder requests, we compare GTAP predicted outputs with totality of global changes based on FAO data

GTAP Predicted Conversion of Forestland for Three Biofuels



Approach B, YPE = 0.175, PAEL_US = 0.4, PAEL_Brazil = 0.2, Base TEM values

Comparison of GTAP Predicted Conversion of Forestland with FAO Data



Evaluation of Uncertainty

Uncertainty: Overview

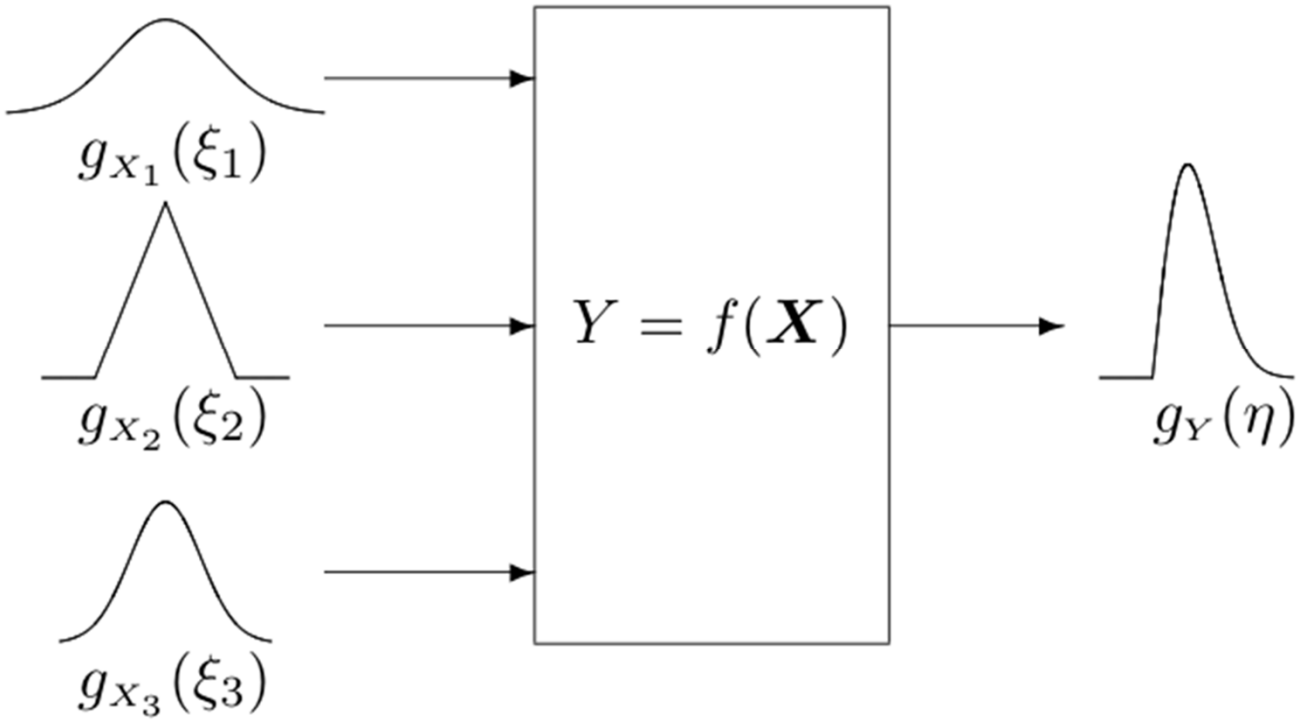
- Monte Carlo (MC) framework
- Systematic approach to uncertainty analysis
- Identifies most sensitive parameters and model components; guides further research
- Provides an estimate of expected value
- Joint model comprising GTAP and AEZ-EF

Uncertainty: Parameters in GTAP/AEZ-EF

- AEZ-EF model has 45 parameters
  - Many are matrices of 18 AEZs by 19 regions
  - Carbon stocks, growth rates, change factors
- GTAP model has 53 behavioral parameters
  - Many are matrices of 19 regions by 35 sectors
  - Most are elasticities of substitution

Uncertainty: Details of MC Inputs

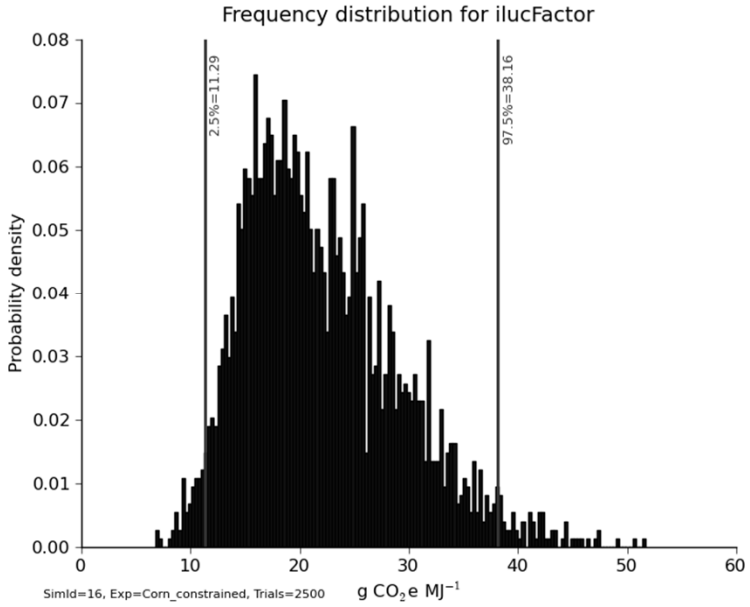
Parameters used distributions and ranges developed in consultations with experts and from review of published literature



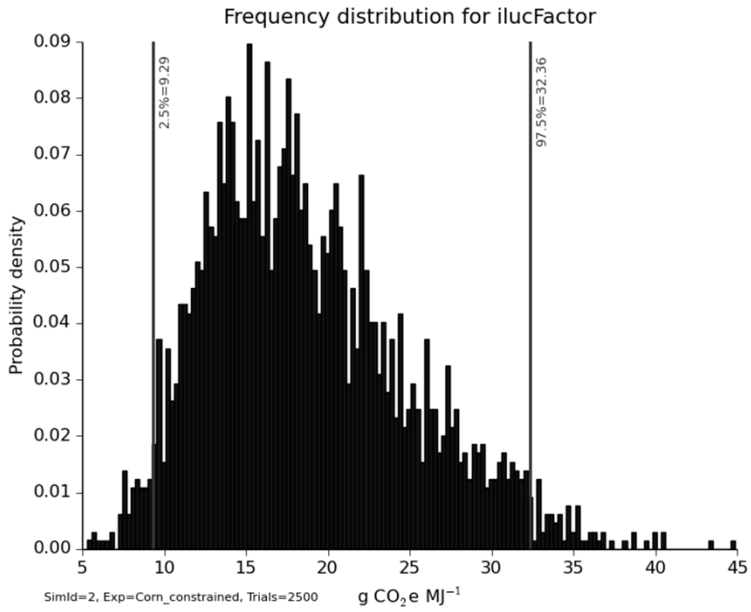
Uncertainty: Details of MC simulations

- Conducted simulations 1000s of times and saved results
- For each simulation, values are selected from input distribution
- Accumulated outputs describe a frequency distribution
- Presented preliminary probability distributions at the March 2014 workshop

Uncertainty: Probability Distributions (Corn Ethanol)

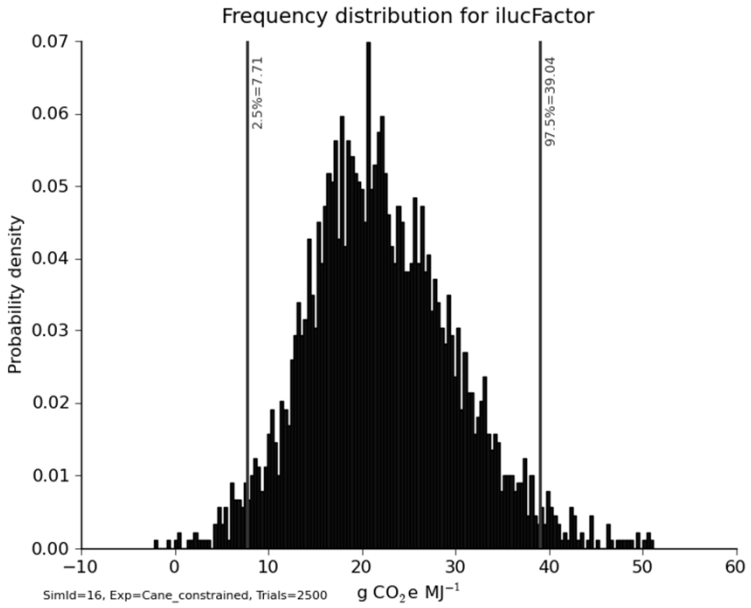


Approach A

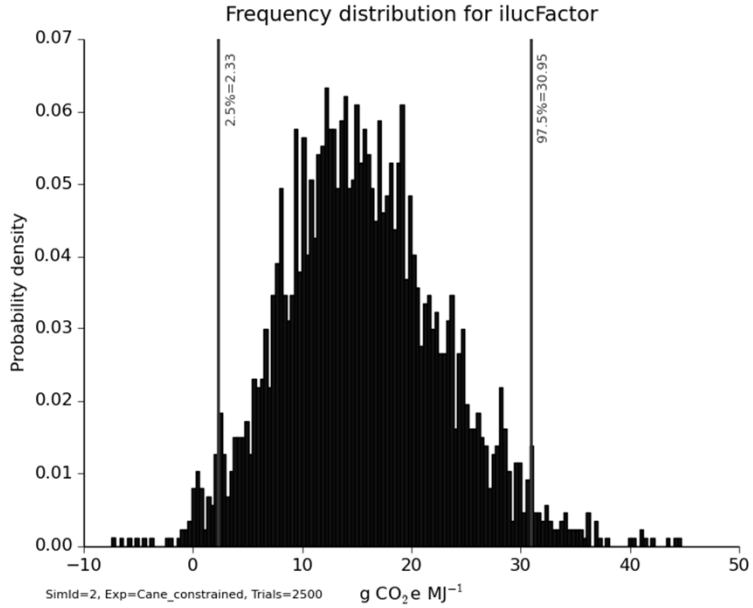


Approach B

Uncertainty: Probability Distributions (Sugarcane Ethanol)

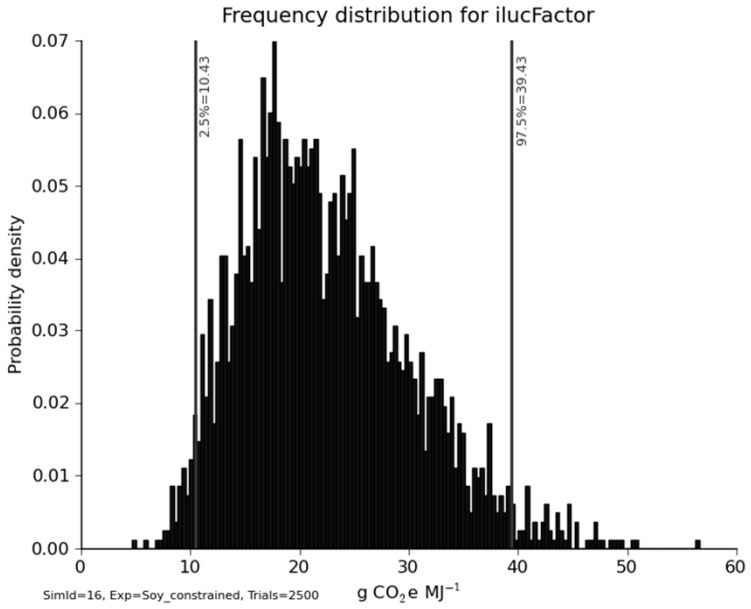


Approach A

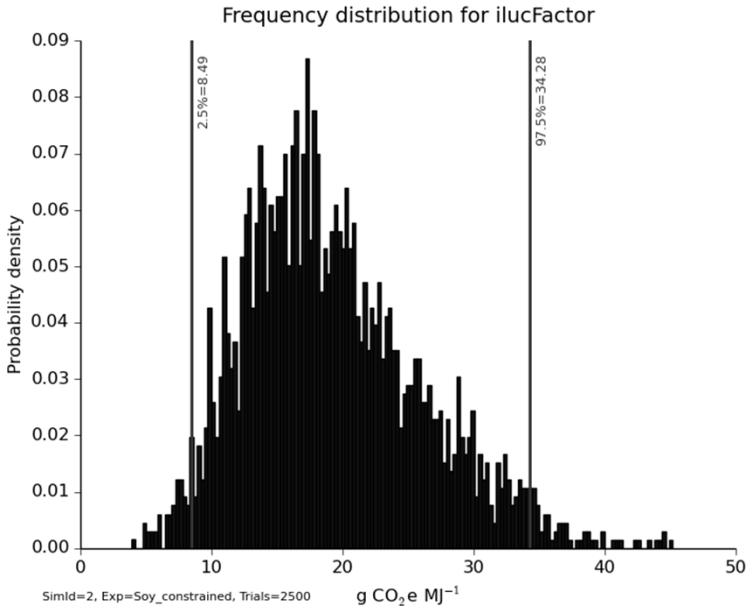


Approach B

Uncertainty: Probability Distributions (Soy Biodiesel)



Approach A



Approach B

Future Updates

GTAP: Effects of Fertilizer, Livestock, and Paddy Rice Emissions

- GTAP simulations predict changes in paddy rice, livestock quantity, crop intensification, new crop production, etc., but the current analysis does not account for corresponding changes in GHG emissions
- What are the net impacts by including these changes in emissions?
  - CH_4 from paddy rice cultivation (potential credits)
  - CH_4 and N_2O from livestock enteric fermentation and manure (potential credits)
  - N_2O from fertilizer use for crop intensification (potential deficits)
  - N_2O from new crop production (potential deficits)

GTAP: Emissions (cont.)

- Current challenges
  - Potential double counting between CA-GREET and GTAP
  - Methodological inconsistency
- Timeframe to address these emissions
  - Requires update to emissions database
  - Resolve potential double counting issue
  - Will be considered in long-term updates to GTAP

GTAP: Forestry Sector Issue

- GTAP does not make distinction between managed and unmanaged forest
- Given this issue, it is possible that the wood products market needs more attention in future work
- Current version of model includes adjustments in ETL values which may be a temporary solution to this issue
- Will be addressed in long-term updates to GTAP

Schedule for iLUC Analysis

iLUC: Schedule for 2014-2015

- Feedback requested by October 15, 2014
- Evaluate and respond to feedback from workshop, and modify model and approach, if necessary
- Workshop planned in October 2014
- Evaluate, respond, and modify model if necessary

iLUC: Schedule for 2014 -2015 (cont.)

- Peer Review of LCFS will include iLUC review
- Proposed regulations filed with OAL in December 2014
- Anticipated Board Hearing on LCFS and ADF in February 2015
- If Board adopts regulations, final regulations filed with OAL in 2015 to take effect January 1, 2016

iLUC: Long-term Schedule

- Address Forestry issue in the model
- Account for Fertilizer, Livestock, and Paddy Rice emissions in a consistent manner
- Include analysis for Cellulosic Feedstocks
- Develop and validate dynamic GTAP model

Acknowledgements

- Purdue University: Wally Tyner and Farzad Taheripour
- UC Davis: Rich Plevin, Sonia Yeh, and David Rocke
- UC Berkeley: Mike O'Hare
- U. Wisconsin: Holly Gibbs

Workshop Feedback

- Request feedback by October 15, 2014
- Submit via email to Katrina Sideco at ksideco@arb.ca.gov

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Thank you