International Institute for Applied Systems Analysis
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science for global insight

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Argonne National Laboratory

Assessing Land Use Change Impacts of Conventional and Advanced Biofuels Consumed in the EU

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In collaboration with
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Stefan Frank, Petr Havlik, Nicklas Forsell and others (IIASA)
Marten van der Berg (E4Tech)

Outline

- Update on EU ILUC study with GLOBIOM
  1. Approach and methodology
  2. Model improvements
  3. Scenarios

- Taking a step back…

I – Approach and methodology

EU ILUC GLOBIOM study

- Assignment by DG ENER, European Commission, other DGs involved
- Consortium: Ecofys, IIASA, E4tech
    - Quantify ILUC emissions of conventional and advanced biofuels consumed in the EU
        - Now talking about quantifying total LUC
    - Follow-up of MIRAGE-BioF study from IFPRI
    - Global PE model: GLOBIOM
- September 2013 – Autumn 2015…
- Final report publication expected soon

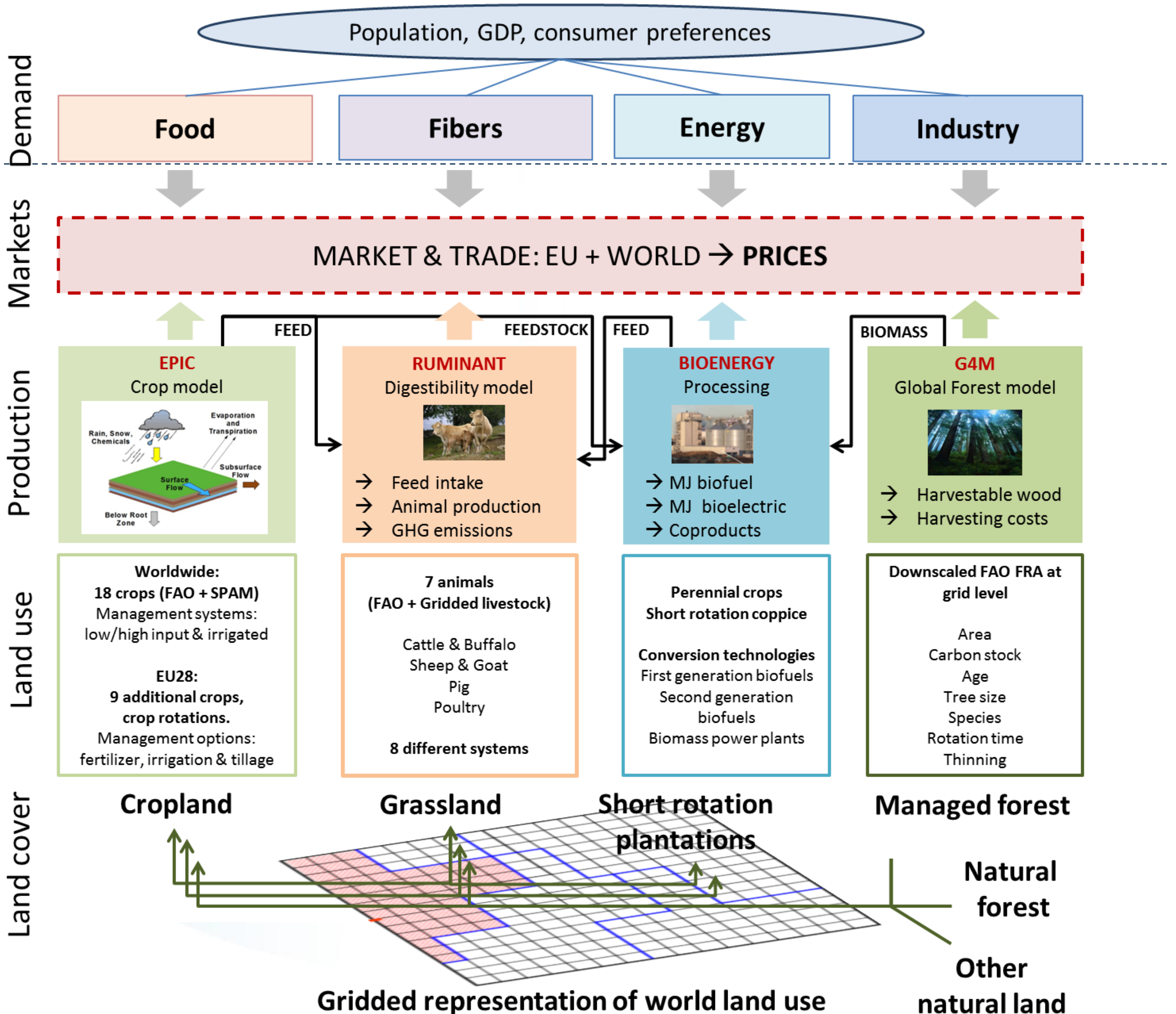
More inclusive process

- Stakeholder consultation
  - Industry 1st and 2nd generation
  - NGOs on transportation fuel regulation and on environment
  - 1st consultation: Inventory of model(s) limitations and desired improvements
  - 2nd consultation: Selection of model improvements, choice of baseline/scenarios
- Interactive process
  - Face to face meetings, phone calls
  - Dedicated website: www.globiom-iluc.eu
  - Email address for questions and comments: ILUC@ecofys.com
  - Model documentation / list of improvements (/ results tba) online
  - FAQs document
- Advisory committee
  - Scientists and experts on land use change impact of biofuels
  - Balanced: one representative proposed by industry and one by NGOs
    - R. Edwards, J. Fabiosa, D. Laborde, C. Malins, A. Nassar, D. O'Connor, K. Overmars, R. Plevin, P. Bindraban
  - Advisors and reviewers

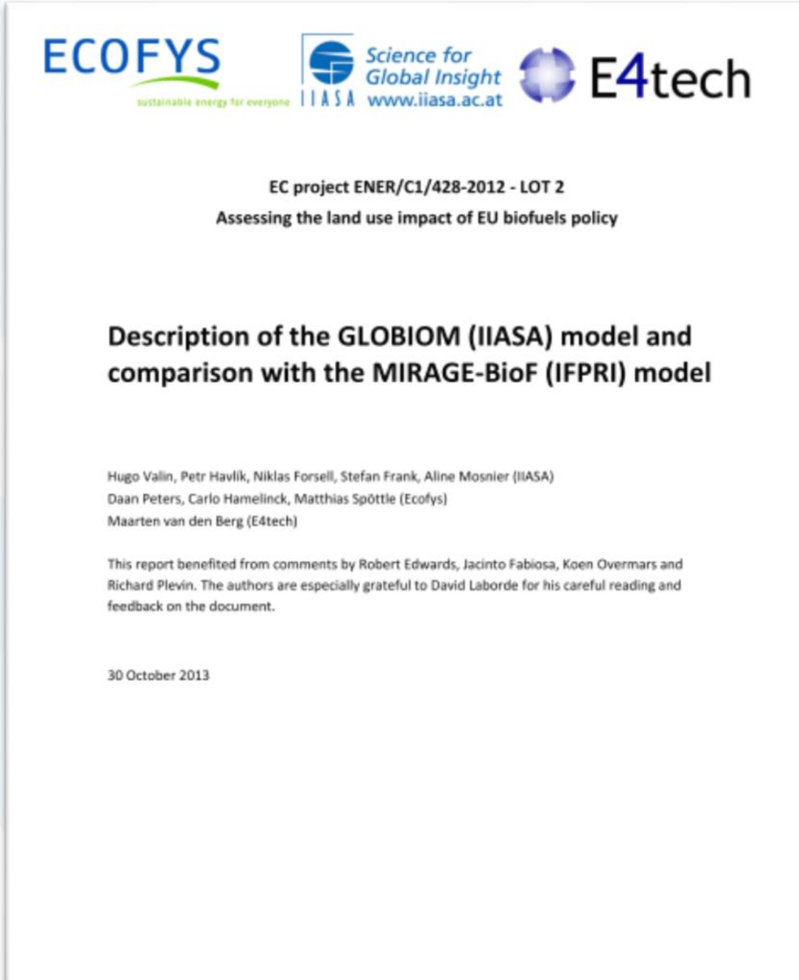
GLOBIOM

- Global scale model based on grid cell resolution (50 x 50 km)
- Partial equilibrium
  - agricultural, wood and bioenergy markets
  - 25 world regions + 28 Member states
  - bilateral trade
- Base year 2000
- Time-step: 10 years, typical time-horizon 2020/2050

- Significant involvement on land use change projects
  - Reduction of Emissions from Deforestation and Degradation (REDD)
  - Agricultural prospective
  - Climate change impact, adaptation and mitigation
  - Bioenergy


Population, GDP, consumer preferences
Demand
Food
Fibers
Energy
Industry
Markets
MARKET & TRADE: EU + WORLD → PRICES
FEED
FEEDSTOCK
FEED
BIOMASS
Production
EPIC
Crop model
Rain, Snow, Chemicals
Evaporation and Transpiration
Subsurface Flow
Surface Flow
Below Root Zone
RUMINANT
Digestibility model
→ Feed intake
→ Animal production
→ GHG emissions
BIOENERGY
Processing
→ MJ biofuel
→ MJ bioelectric
→ Coproducts
G4M
Global Forest model
→ Harvestable wood
→ Harvesting costs
Land use
Worldwide:
18 crops (FAO + SPAM)
Management systems:
low/high input & irrigated
EU28:
9 additional crops,
crop rotations.
Management options:
fertilizer, irrigation & tillage
7 animals
(FAO + Gridded livestock)
Cattle & Buffalo
Sheep & Goat
Pig
Poultry
8 different systems
Perennial crops
Short rotation coppice
Conversion technologies
First generation biofuels
Second generation biofuels
Biomass power plants
Downscaled FAO FRA at grid level
Area
Carbon stock
Age
Tree size
Species
Rotation time
Thinning
Land cover
Cropland
Grassland
Short rotation plantations
Managed forest
Natural forest
Other natural land
Gridded representation of world land use

Differences with MIRAGE-BioF

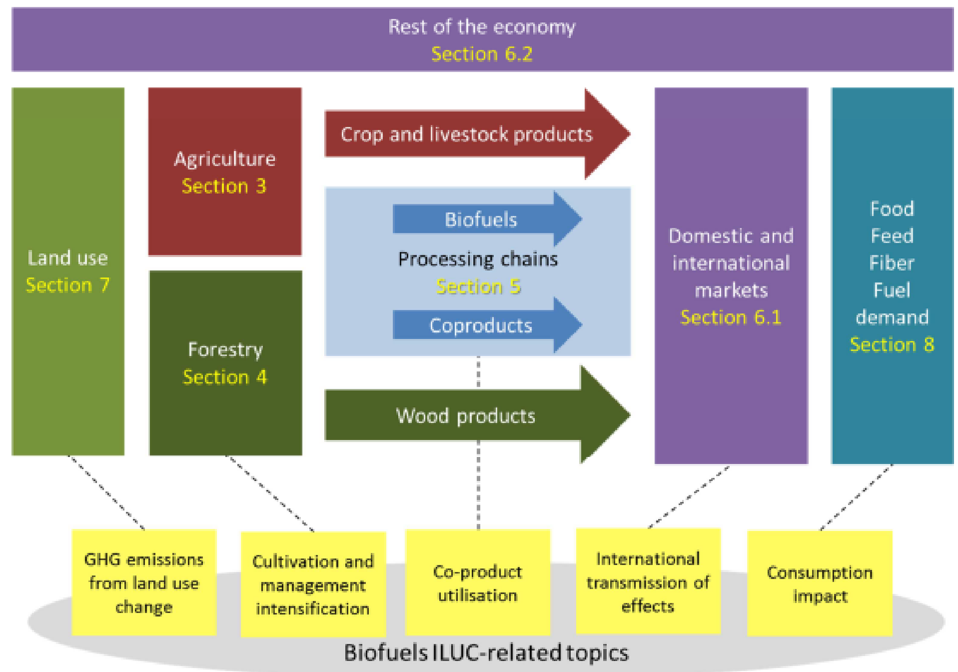

EC project ENER/C1/428-2012 - LOT 2
Assessing the land use impact of EU biofuels policy

Description of the GLOBIOM (IIASA) model and comparison with the MIRAGE-BioF (IFPRI) model

Hugo Valin, Petr Havlík, Niklas Forsell, Stefan Frank, Aline Mosnier (IIASA)
Daan Peters, Carlo Hamelinck, Matthias Spöttle (Ecofys)
Maarten van den Berg (E4tech)

This report benefited from comments by Robert Edwards, Jacinto Fabiosa, Koen Overmars and Richard Plevin. The authors are especially grateful to David Laborde for his careful reading and feedback on the document.

30 October 2013



II – Improving the model

Improving the model

- Stakeholder and advisory committee consultation (2013)
  - 37 possible improvements listed
- Decision on final improvements was made on following criteria:
  - Relevance of the improvement
  - Effort required by the improvement
  - Overall effort budget (12 effort points)
- Second consultation round early 2014
  - 11 improvements selected
  - 13 effort points
  - Simplified solutions for some difficult topics to keep them in the list

List of improvements as decided in March 2014

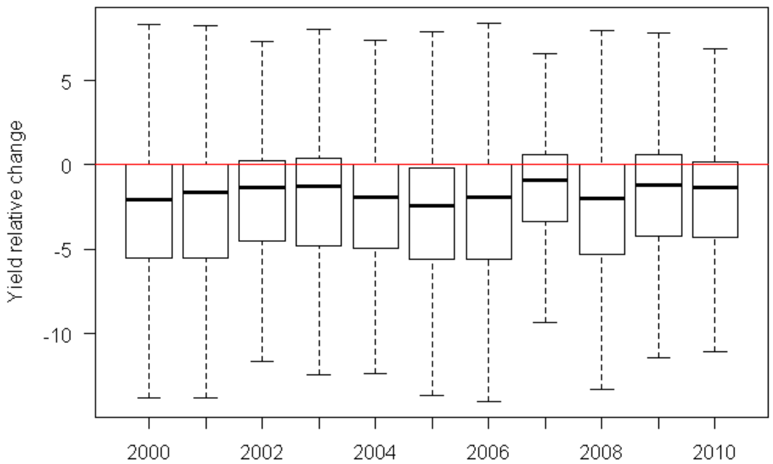
Item	Topic	Effort units
1	Impact on agricultural residues on yield and SOC	2
4+5	Carbon sequestration in annual and perennial crops	1
7 + 29	Peatland emission factors + Expansion of plantations into peatland	1
8	Expand inclusion of soil organic carbon (SOC) to rest of the world	1
9	Forest regrowth and reversion time	1
11	Refine co-product substitution based on protein and energy content	2
15	Include effect of multi-cropping	Baseline
21	Imperfect substitution of vegetable oils	2
24+25	Separate representation of Argentina, Indonesia, Malaysia and Ukraine	2
27	Represent unused agricultural land in Europe	Policy scenario
34+35	Refine supply chain coefficients (oilseed crushing, ethanol production coefficients)	1
Total effort		**13**

1: Modelling straw removal in GLOBIOM

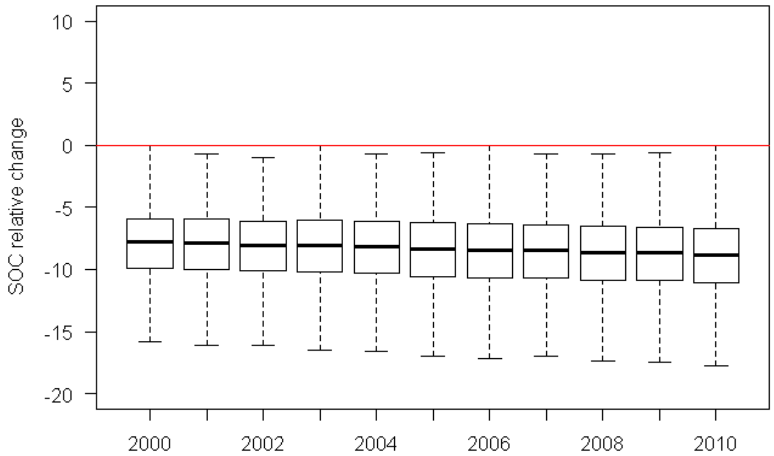
- Three production systems
  - No straw removal
  - Sustainable removal (~40%)
  - Full removal (90%)

- Using the EPIC model to determine impact of residue removal on:
  - yield
  - soil organic carbon

Yield effect

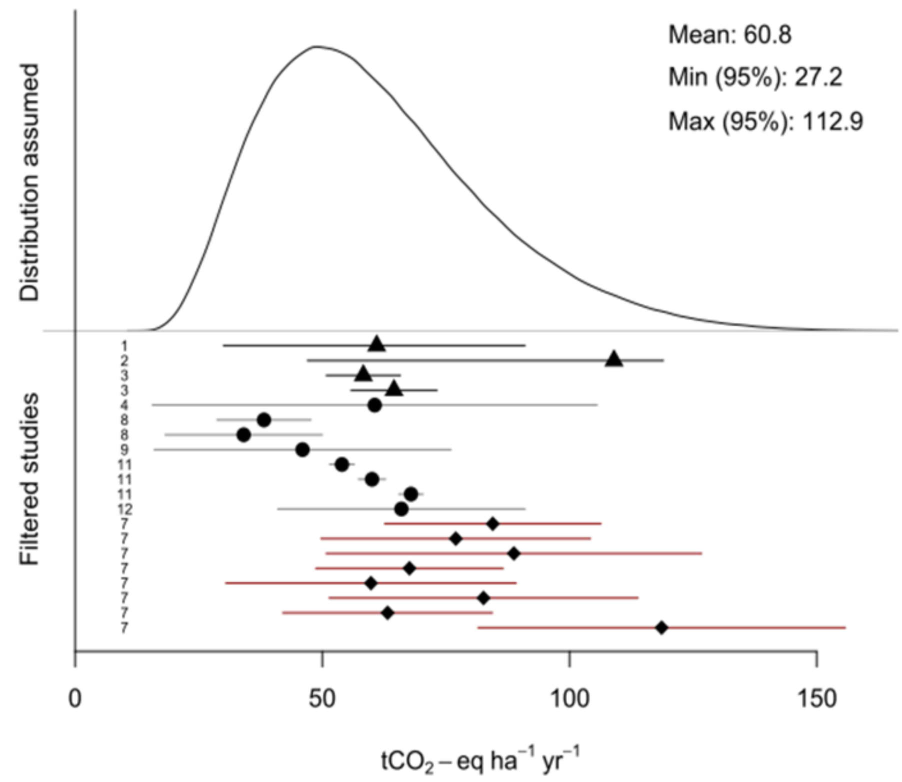


SOC effect



7: Emission factors for palm plantations on peat

- Extensive literature review
  - Closed chambers studies
  - Subsidence studies
  - Previous reviews
- Round of AC consultation
- Own model based on subsidence approach
- Covers the range of subsidence parameters in the literature
- Mean higher than IPCC, lower than value used by EPA



11: Representation of biofuel co-product in GLOBIOM

- Own displacement method calculation based on substitution of:
  - Metabolisable or net energy
  - Crude protein intake
- Product and animal species specific
- Nutrients content calculated based on:
  - NRC data for traditional feedstuff (crops, protein meals)
  - More recent literature on DDGS (FAO report)

	Corn DDGS	Wheat DDGS	Sugar beet pulp	Rapes eed meal	Sunflo wer meal
Beef					
Wheat	0.791	0.582	0.89	-0.094	-0.434
Soya meal	0.371	0.547	-0.083	0.844	1.137
Dairy cow					
Wheat	0.753	0.506	0.95	-0.006	-0.329
Soya meal	0.384	0.571	-0.102	0.816	1.103
Swine					
Wheat	0.686	0.437	0.944	0.139	-0.112
Soya meal	0.405	0.593	-0.1	0.769	1.034
Poultry					
Wheat	0.375	0.224	0.083	-0.038	-0.091
Soya meal	0.505	0.662	0.176	0.826	1.027

15: Representing multi-cropping in GLOBIOM

- Assessement based on FAO data and remote sensing literature
- Trend added to the baseline
- Taking into account biophysical limitations

Region with multi-cropping	Harvested area – cropland (1000 ha, only >1Mha reported)	Cropping intensity	Annual growth rate (2000-2011)	Maximum cropping intensity (Ray and Foley, 2013)
China	29,089	1.53	0.40%	1.75
Nigeria	8,537	1.26	-1.70%	2
India	6,514	1.32	0.70%	1.63
Bangladesh	5,544	1.63	1.10%	1.99
VietNam	3,865	1.47	-0.50%	1.95
Philippines	2,779	1.28	0.20%	2
Myanmar	2,551	1.24	1.60%	1.8
Nepal	2,052	1.84	0.80%	1.06
Egypt	1,271	1.38	0.50%	1.01
Others (< 1 Mha)	1,347	1.02	--	--
TOTAL	63,549	1.13	--	--
Brazil		0.78	0.90%	1.71
World		0.82		

III – Scenarios

List of feedstocks of interest

Conventional feedstocks	2nd generation feedstocks
Wheat	Miscanthus/switchgrass
Maize	Short rotation plantation
Barley	Forest residue
Sugarbeet	Cereal straw
Sugarcane	
Silage maize (biogas)	
Sunflower oil	
Palm oil	
Rapeseed oil	
Soybean oil	

Scenarios set

#	Baseline and scenarios	Nr.	Sensitivity analysis
	Baseline		
A0	Baseline: global trends between 2000 and 2030		YES
	Feedstock scenarios		
A	**"Marginal feedstock":** A0 +1% biofuel consumption per feedstock	13	YES
A1	**"Marginal feedstock for cereal straw"**: A0 + 1% shock of straw ethanol for EU and for three selected Member States	4	YES
A2	**"Marginal feedstock groups"**: as A, but with crop groups (ILUC proposal)	3	YES
	Policy scenarios		
B	**"EU biofuel mix in 2020":** A0 + biofuel consumption forecasts from MS NREAPs	1	YES
B1	**"EU biofuel mix in 2020 with 7% cap":** B + maximum of **7%** conventional biofuels	1	NO
	Explorative scenarios		
C	**"Biofuels + increased use of abandoned land in EU"**: incentivised land expansion into EU abandoned land in the baseline + Scenario B	1	NO
C1	**"Biofuels + low deforestation ":** assumed lower deforestation (two levels) worldwide and halting of peatland conversion in the baseline compared to recent trends + Scenario B	3	NO
C2	**"Biofuels + high deforestation":** assumed higher deforestation worldwide in the baseline compared to recent trends + Scenario B	1	NO
	TOTAL NUMBER OF SCENARIOS	**27**	

300 runs

6,600 runs

Results and analysis

- For each scenario
  - Distribution of impact across demand, coproducts, yield and land expansion
  - Total GHG emissions for 20 years (also test with 50 years) → Annualized LUC emission factor
  - Sources accounted
    - Above and below living biomass in vegetation (natural and cultivated land)
      - Land use conversion
      - Foregone sequestration from vegetation regrowth
    - Soil organic carbon
    - Mineral carbon oxidation from peat drainage
- Sensitivity analysis
  - Technical coefficients
  - Economic parameters on supply, demand and trade
  - Emission factors
- Comparison with previous estimates for the EU and other regions

Next steps

- Report publication
- Online results
- Presentation event in Brussels for stakeholders

- Dates to be announced…

The land use change impact of biofuels consumed in the EU

Quantification of area and greenhouse gas impacts

By:

Hugo Valin (IIASA), Daan Peters (Ecofys), Maarten van den Berg (E4tech), Stefan Frank, Petr Havlik, Nicklas Forsell (IIASA) and Carlo Hamelinck (Ecofys), with further contributions from: Johannes Pirker, Aline Mosnier, Juraj Balkovic, Erwin Schmid, Martina Dürauer and Fulvio di Fulvio (all IIASA)

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EUROPEAN COMMISSION

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A cooperation of Ecofys, IIASA and E4tech

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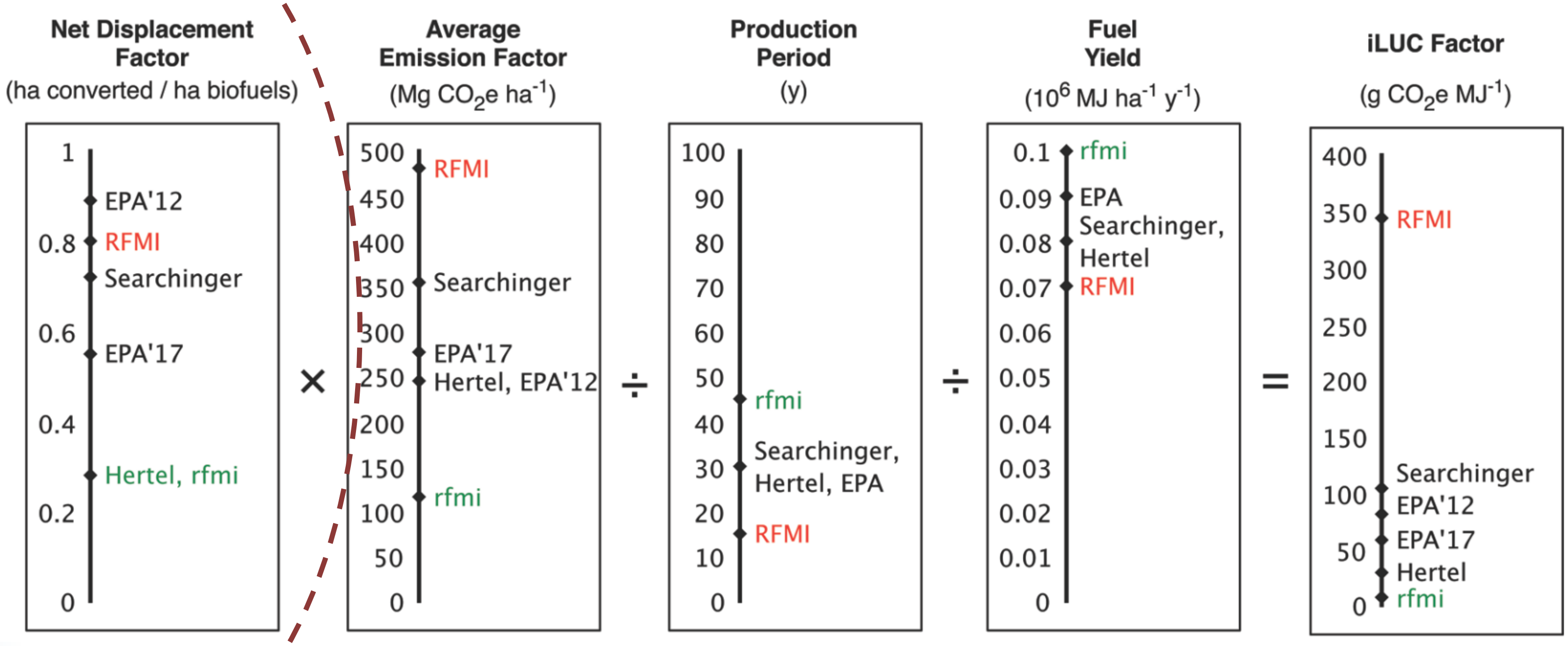
Chamber of Commerce 30161191 ii

...taking a step back

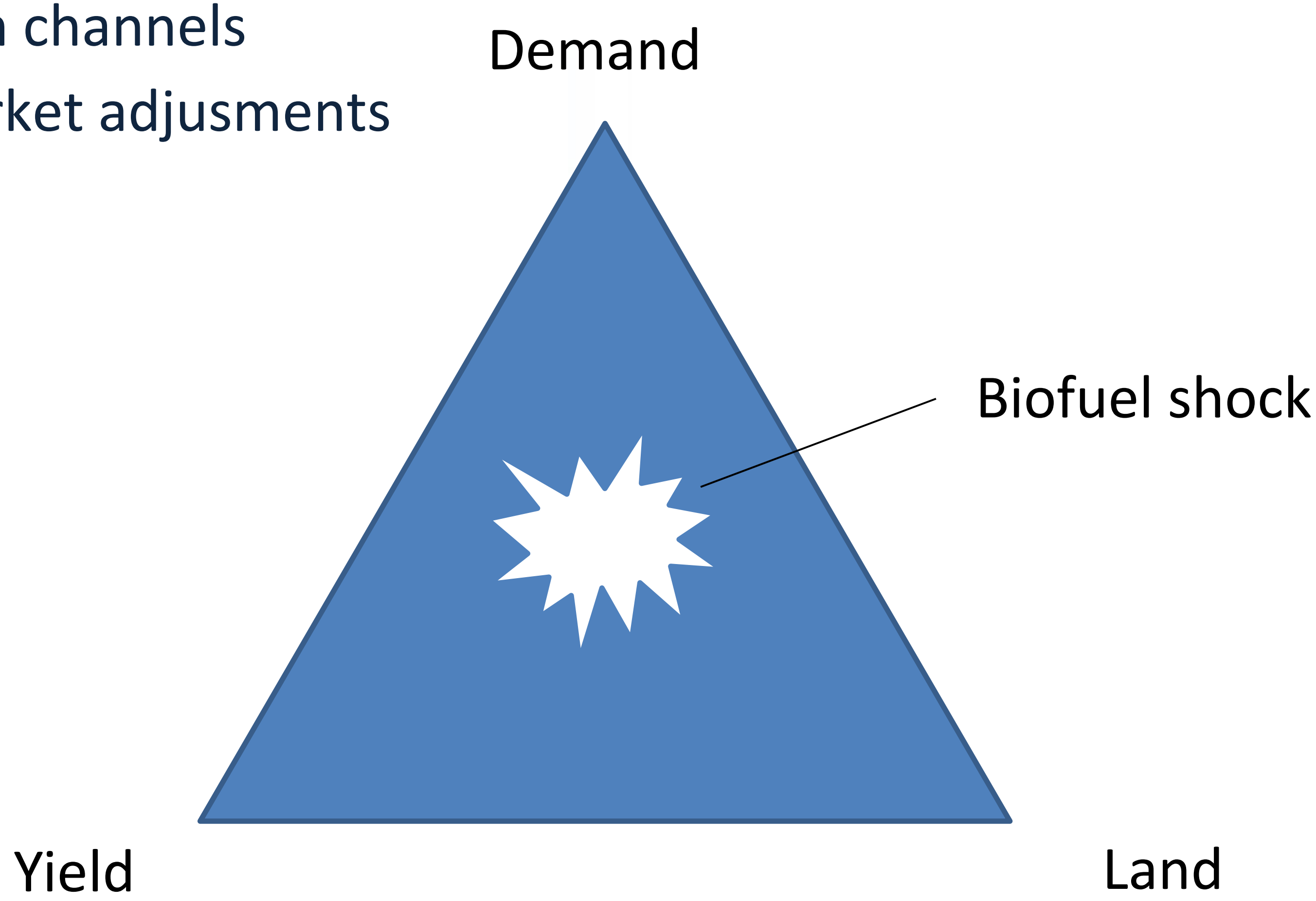
Decomposition approaches



Source: Plevin et al. 2010

Main drivers of market responses

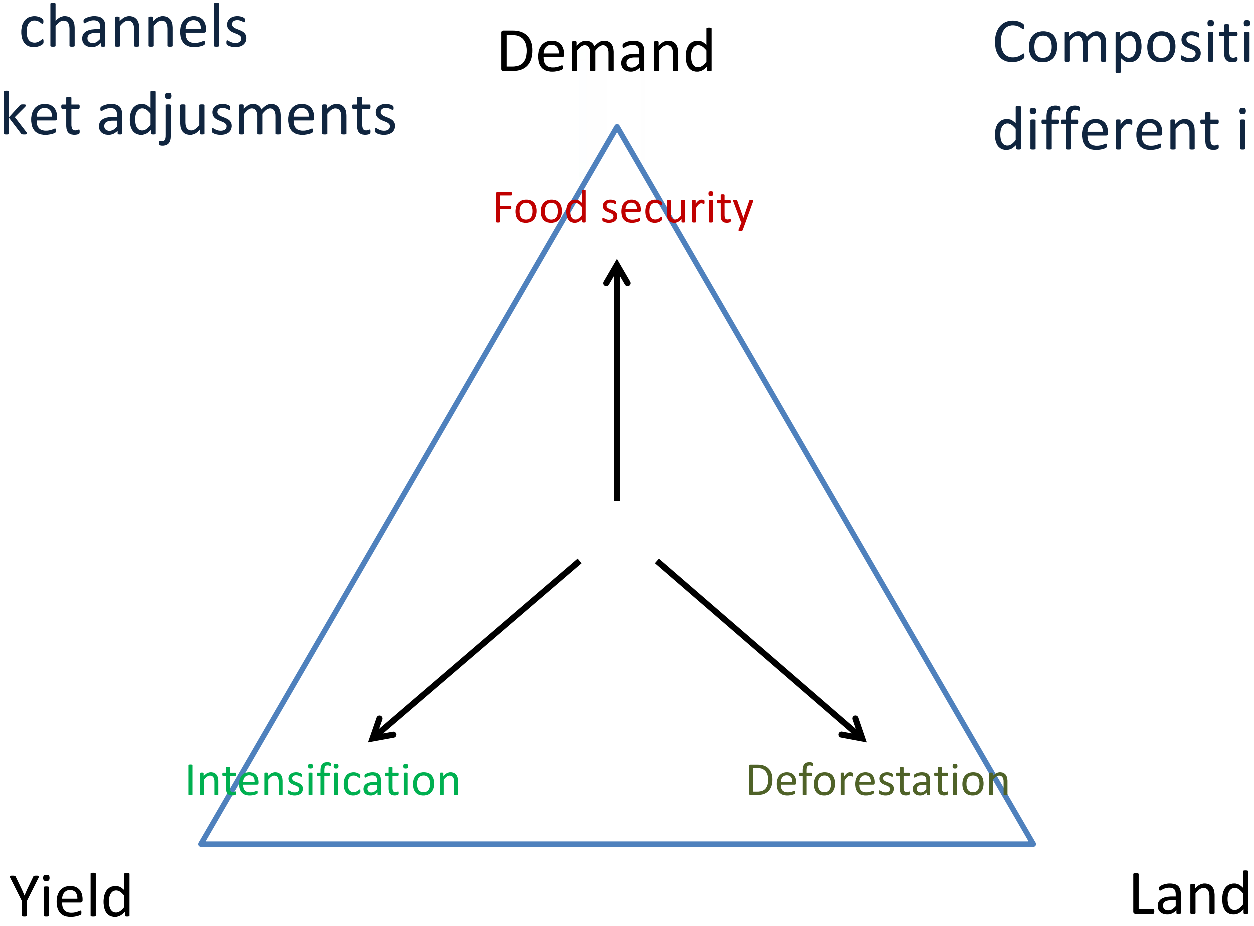
3 main channels
of market adjusments



Main drivers of market responses

3 main channels
of market adjusments

Composition of
different impacts



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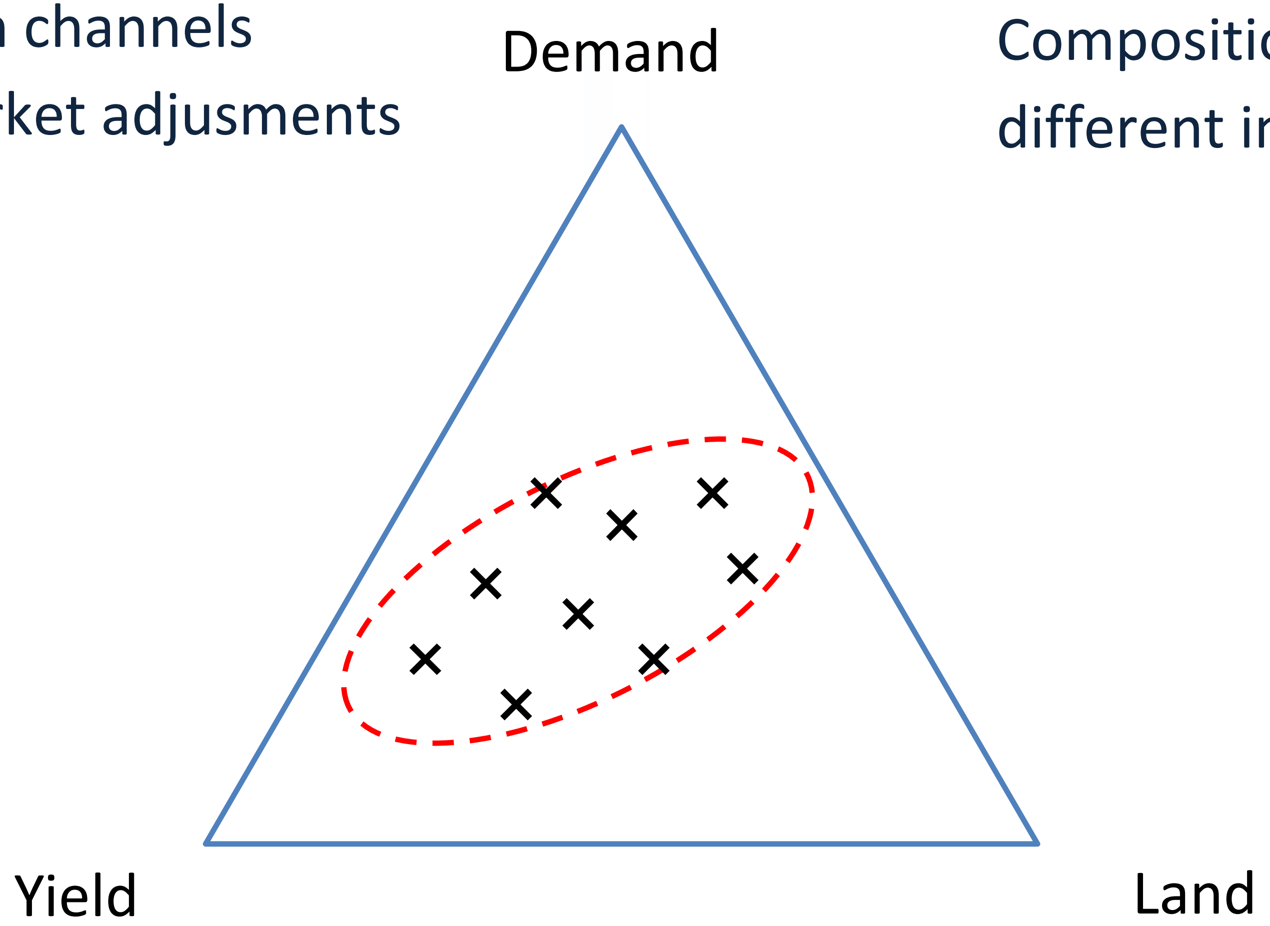
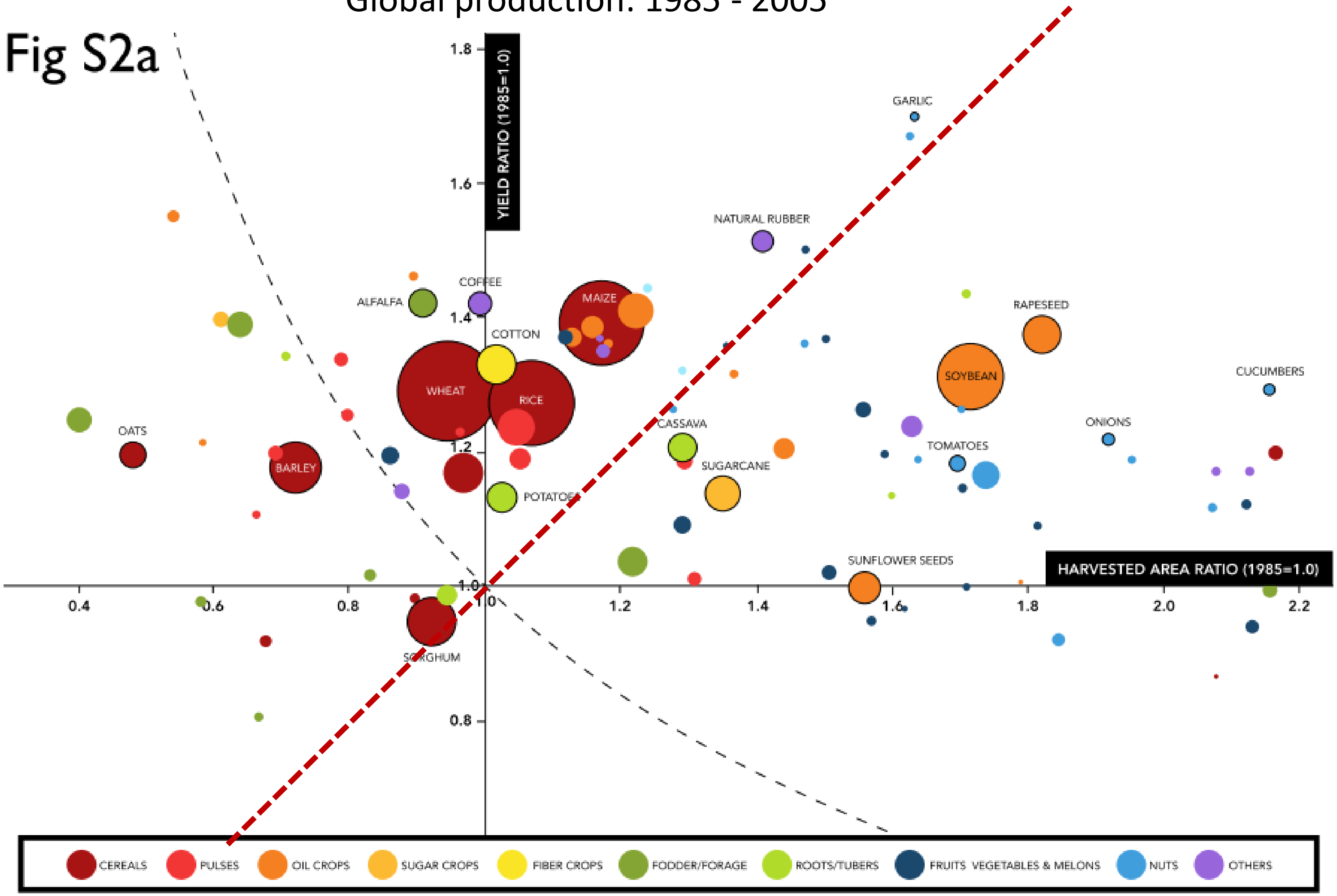


Intensive versus extensive margin

Global production: 1985 - 2005

Fig S2a



Source: Foley et al., 2011, Nature

Approach to reduce uncertainty

- Possible to express the response as a function of elasticities

$$q_L^* = \frac{\overbrace{\Delta_A^D + \Delta_L^S + \Delta_L^D}^{\text{Market shocks}}}{1 + \eta_A^{S,I}/\eta_A^{S,E} + \eta_A^D/\eta_A^{S,E}} - \Delta_L^S,$$

Land response   Yield elast   Demand elast   Land elast

Source: Hertel, 2011

- Back to econometric uncertainty ranges
- Literature review and collection of yield, demand and land supply elasticities

Application to the ILUC of biofuels

- Approach departing from applied modelling
- Tractable, transparent
- Small analytical model

ILUC = f (S,E)

with S initial state

E elasticity values

$$\mathbf{\Gamma}_r = \mathbf{YLE}^y + \mathbf{Y}_m\mathbf{LE}^s + \mathbf{Y}_m\mathbf{LE}^e - \mathbf{DE}^a \tag{C.1}$$

$$\tilde{\mathbf{\Gamma}}_{r_0} = \sum_r \mathbf{A}_{r_0,r}\mathbf{\Gamma}_r \tag{C.2}$$

$$\mathbf{\Phi}_{r_0} = \left[\sum_r \mathbf{Y}_m \cdot \mathbf{A}_{r_0,r}\mathbf{L}_r\mathbf{E}_r^e\right]\tilde{\mathbf{\Gamma}}_{r_0}^{-1} \tag{C.3}$$

$$\mathbf{W}_{r_0,r} = \mathbf{A}_{r_0,r}\mathbf{L_r}\mathbf{E}_r^e \cdot \left[\sum_{r'} \mathbf{A}_{r_0,r'}\mathbf{L}_{r'}\mathbf{E}_{r'}^e\right]^{-1} \tag{C.4}$$

$$\tilde{\mathbf{Y}}_{r_0} = \sum_r \mathbf{W}_{r_0,r}\mathbf{Y}_m \tag{C.5}$$

$$\mathrm{ILUC} = \tilde{\mathbf{Y}}_{r_0}^{-1}\mathbf{\Phi}_{r_0}U_B/\rho_{i_0} \tag{C.6}$$

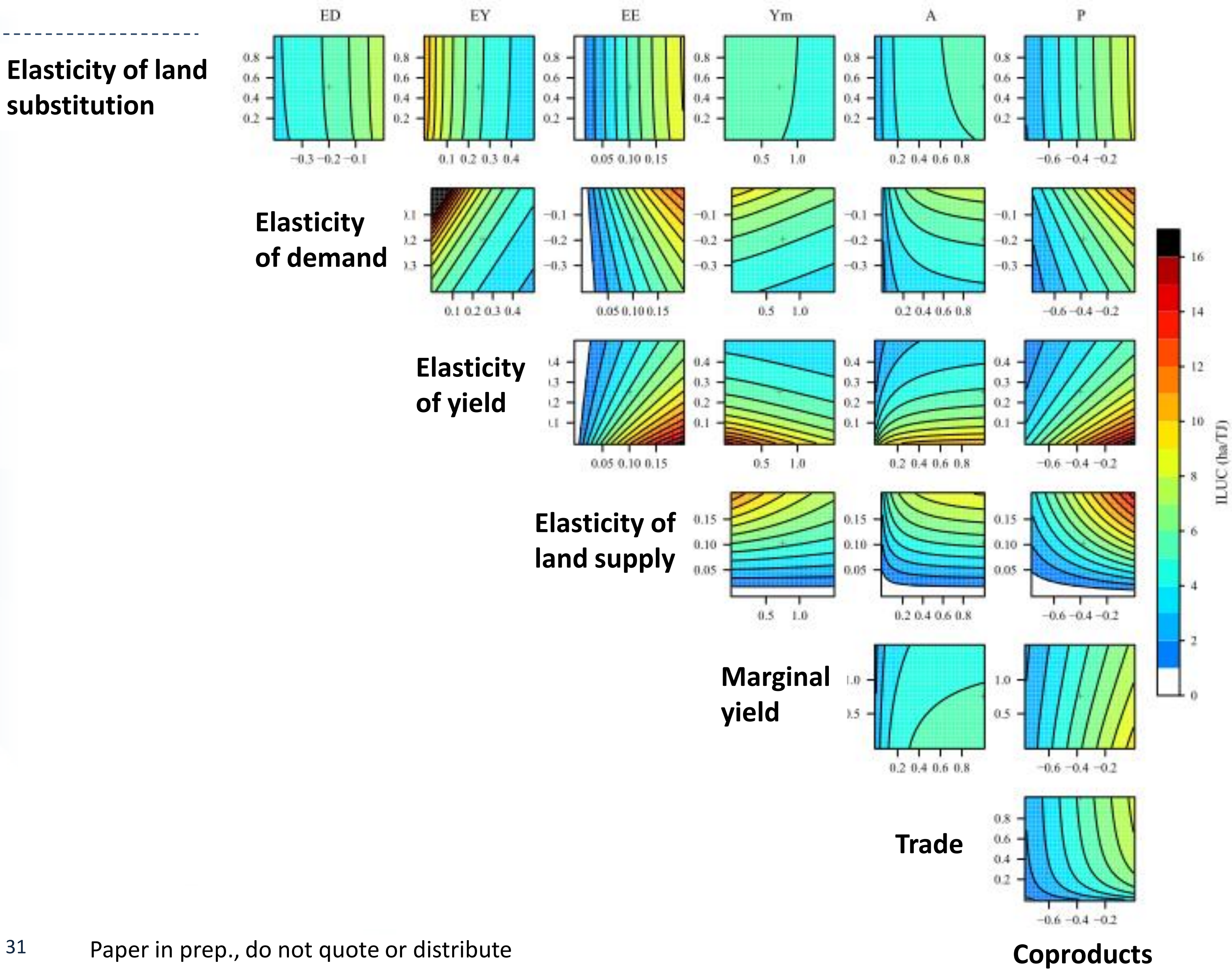
$$\begin{aligned}\mathrm{NDF} &= \rho_{i_0}\, y_{i_0,r_0}\, \mathrm{ILUC} \\ &= \frac{y_{i_0,r_0}}{\tilde{\mathbf{Y}}_{r_0}} \cdot \mathbf{\Phi}_{r_0} \cdot U_B \end{aligned} \tag{C.7}$$

$$\mathrm{EF}_{r_0} = \sum_{c,r} \theta_{c,r}\, e_{c,r}\, \mathbf{W}_{r_0,r}\, N \tag{C.8}$$

$$\text{ILUC factor} = \frac{\mathrm{ILUC} \cdot \mathrm{EF}_{r_0}}{t_{ref}} \tag{C.9}$$

Paper in prep., do not quote or distribute

Exploring the extent of uncertainty



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Conclusion

- EU ILUC study:
  - We are looking forward presenting and discussing our results with the community!
- Looking in the future:
  - More comparability of assessments through common metrics of decomposition
    - Over time
    - Across feedstocks
    - Across regions
    - Across models
  - Sensitivity analysis protocols
- ILUC emission factors
  - Mainly learning how to deal with uncertainty

Thank you for your attention!