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Review of Land Use Change Emission Estimates

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Workshop on Biofuel Greenhouse Gas Modeling
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Introduction

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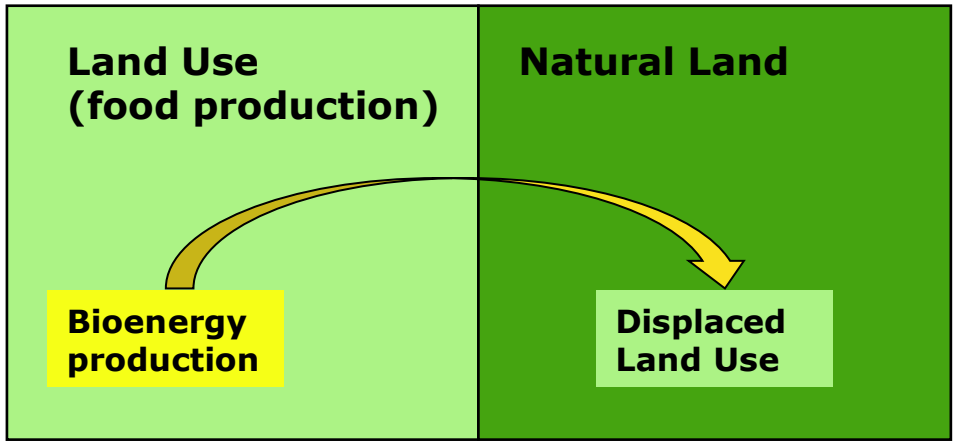
- **The incremental use of land to produce food, feed or fibre can lead to an increase of CO_2 emissions**
  - Direct and Indirect Land Use Change Emission

- **What is *Indirect Land Use Change* (ILUC)**
  - When bioenergy production leads to the displacement the production of land-based products (crops or animals) to other locations, either directly or through changes in agricultural prices



Methods to Study ILUC

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- **Models incorporating economic and biophysical interactions**

1. **Economic Equilibrium Models**: *Partial or General Equilibrium, linked to land-use models*
2. **Hybrid Life Cycle Assessment (HLCA)**: *Linking LCA to economic/land-use models*
3. **Causal-descriptive models**: *Map the chain of causes and effects in response to biofuel demand*
4. **Empirical approaches**: *Based on observations and historic trends in land use and trade*

ILUC Estimates

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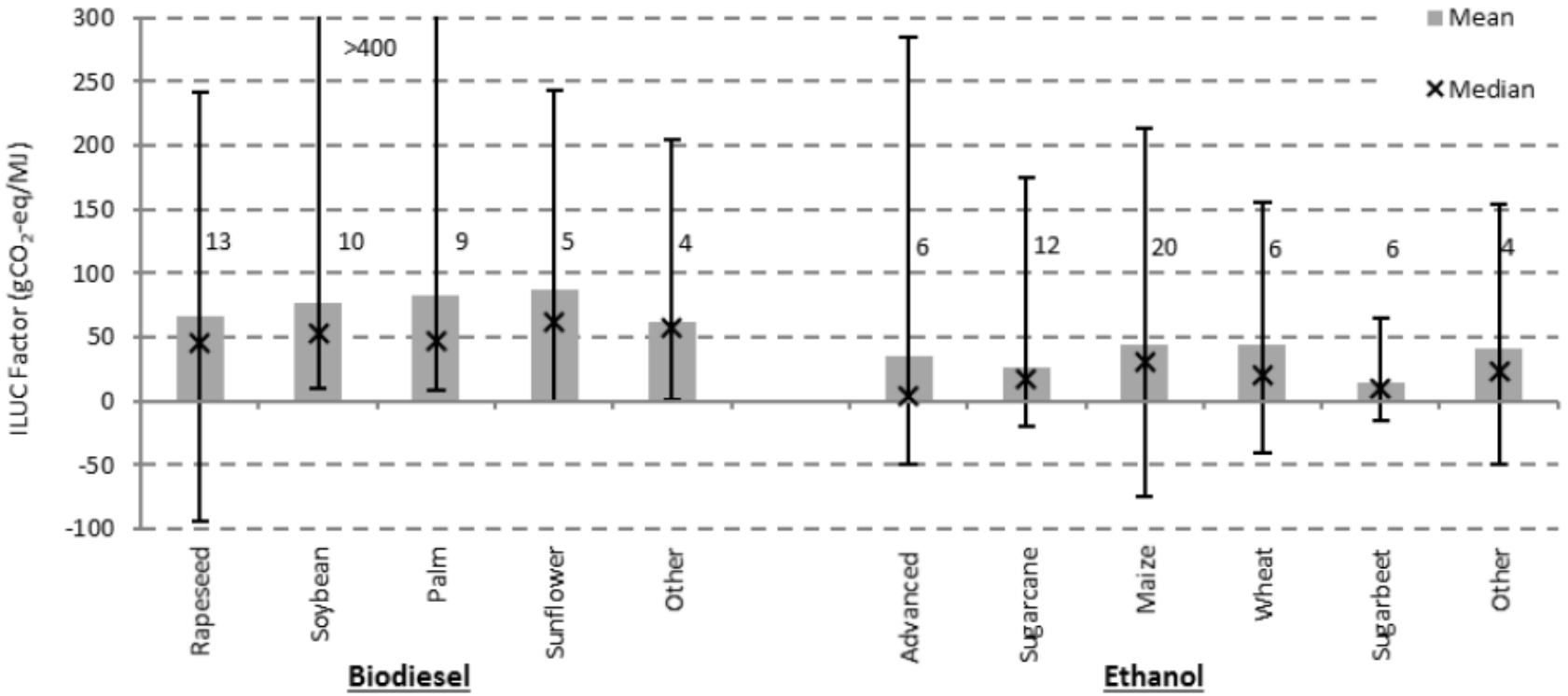
- **Ranges of Results across feedstocks**



Woltjer et al. (2017)

ILUC Estimates

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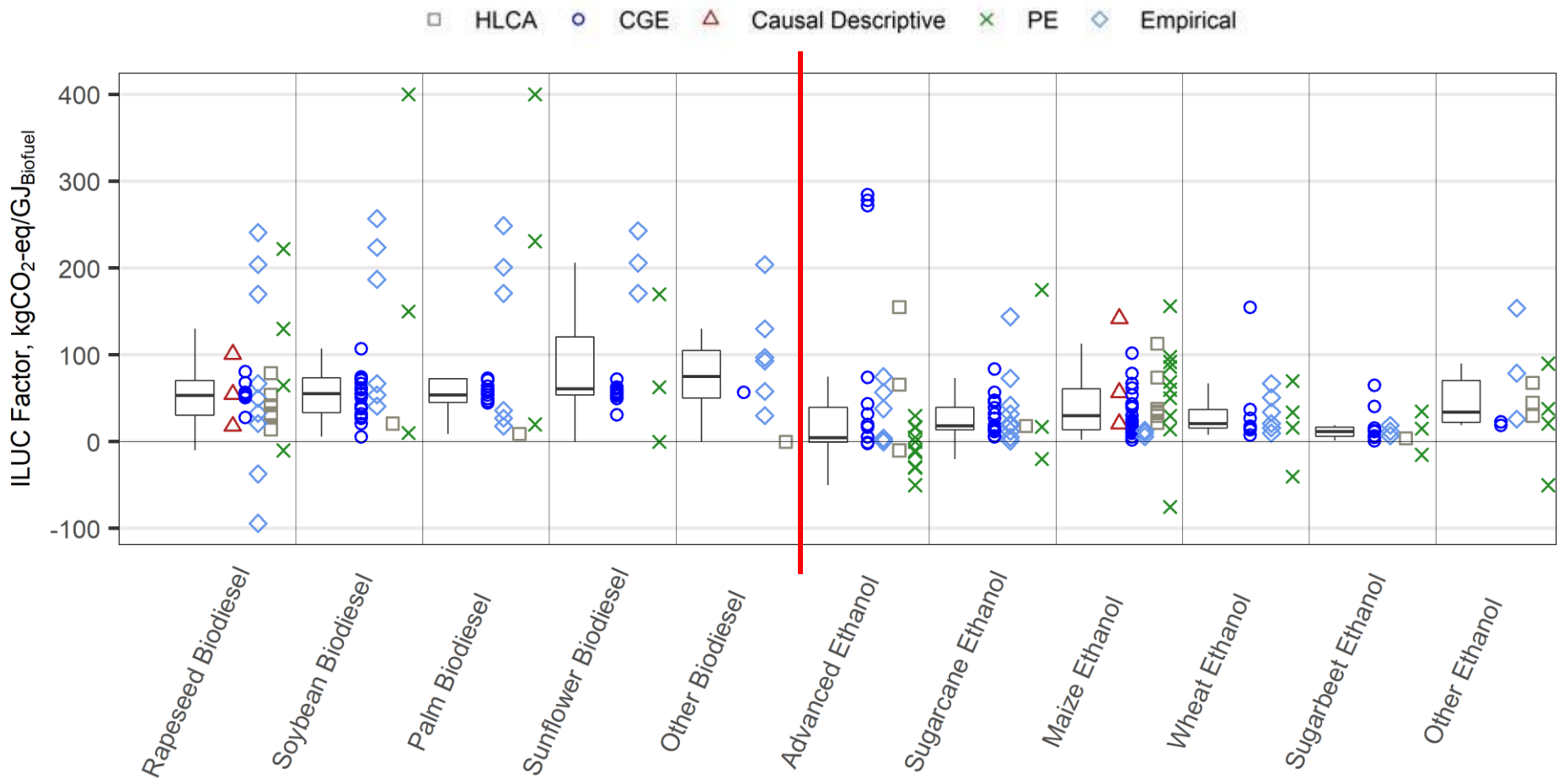
- **Ranges of Results across feedstocks and methodologies**



Daioglou et al. (2020)

Discussion

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- **Robustness**
  - There is variation across and within methods
  - There has ***not*** been any convergence towards robust values as methods become more detailed

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- **Why do estimates vary so much?**
  - Yield productivity improvements
  - Accounting of co-products
  - Price effects on yields and overall consumption (price elasticity)
  - Assumptions and effects on international trade
  - Location of ILUC
  - Land type aggregation and emission factors

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- **Even when there is agreement, there isn't.**
  - Diffferent analyses may agree for different (and inconsistent) reasons
    - *Laborde et al. (2010) and Valin et al. (2015) have similar emission factors for maize-ethanol, with >10x difference in actual LUC, in different continents*
  - Provides limited insight on how much ILUC to expect

Discussion

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- **What can these studies tell us?**
  - Outline the principles which lead to low impact biofuels
    - Biodiesel feedstocks are likely to have greater risks than ethanol feedstocks
    - Perrenial crops may have lower impacts than annual crops
    - Use of residues, degraded/marginal lands, protect land of high ecological value

- **What can they *not* tell us?**
  - There is no single robust emission factor
  - Existing estimates are based on a *bioenergy demand shock*
    - They provide the *marginal* emissions at a given bioenergy level
    - No understanding of the emissions as bioenergy demand may change, or increase to very high levels

Additional approach

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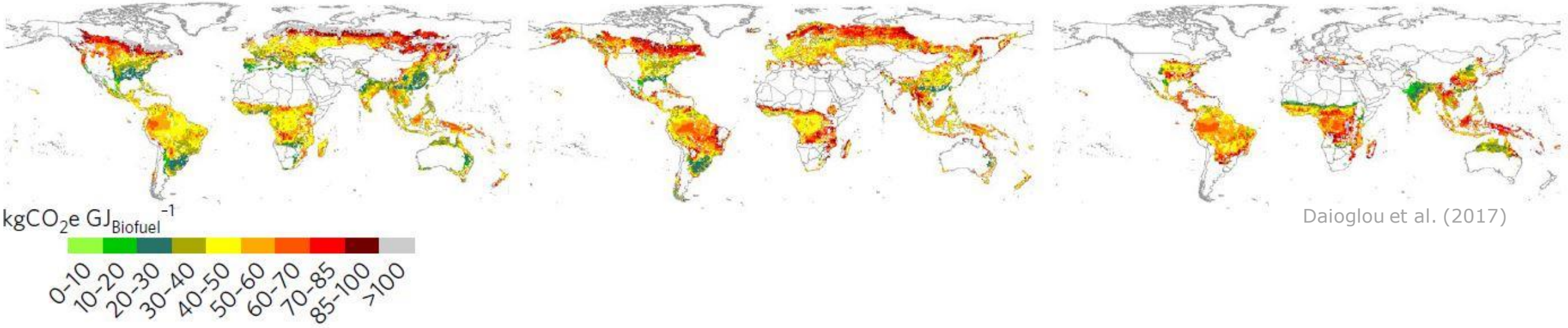
- **Emission-Supply curves**
  - Biophysical approach
  - Estimating the emission factor and bioenergy potential, *spatially explicity*
  - Based on detailed biophysical modelling and data

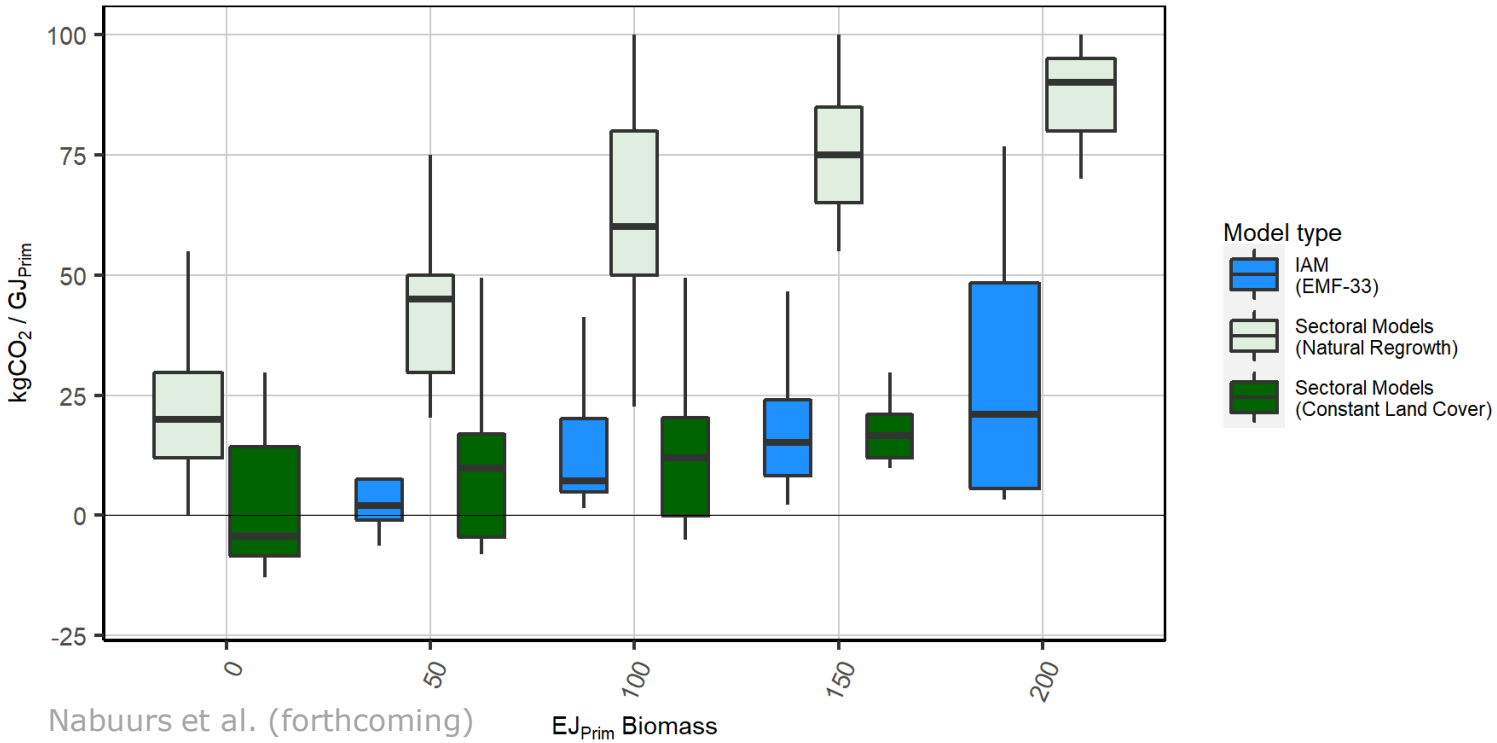
Grass methanol | **Wood methanol** | **Sugarcane ethanol**



Daioglou et al. (2017)

Emission-Supply Curves

- **Review of existing curves**
  - Stylised scenarios of *Integrated Assessment Models (EMF-33)*
  - Partial models with different counterfactual land use in case of no bioenergy production
    - *Constant Land Cover* reflects supply chain emissions and changes in land carbon storage caused by the biomass supply system only
    - *Natural Regrowth* curve attributes counterfactual C-sequestration to the bioenergy system



Nabuurs et al. (forthcoming)

Emission-Supply Curves

- **Provides additional insight**
  - Favourable locations
  - Potential of biomass/bioenergy at given emission level

- **Also suffers from multiple uncertainties**
  - Development of crop yields
  - Treatment of counterfactual
  - Land aggregation and c-stock dynamics
  - Explicit assumptions
    - Biomass will be grown on the best locations (from an emission perspective)
    - For partial models competition with food production is ignored
  - Does ***not*** give clear insight on market mediate effects
    - *ILUC modelling*

Conclusion

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- **There is no single emission factor**
  - Irreducible uncertainty remains
  - Poor guiding principle for biofuel, land-use and environmental policy making
- **Yet studies can highlight important elements of a GHG benign bioenergy system**
  - Use of agricultural and forestry residues
  - Perrenials and lignocellulosic feedstocks
  - Focus land expansion on degraded or marginal lands
  - Explicitly protect lands of high ecological value
- **Need to use multiple, complementary, approaches to explore possibilities**
  - Different modelling techniques (*CGE, PE, HLCA, IAM, etc.*)
  - Different approaches (*ILUC, Emission-supply cruves*)
- **Can use these insights to guide policy design and enforcement**

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Thank you!

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Further reading

Daioglou, V., Woltjer, G., Strengers, B., Elbersen, B., Barberena Ibañez, G., Sanchez Gonzalez, D., ... & van Vuuren, D. P. (2020). **Progress and barriers in understanding and preventing indirect land use change**. *Biofuels, Bioproducts and Biorefining*, 14(5), 924-934.

Daioglou, V., Doelman, J. C., Stehfest, E., Müller, C., Wicke, B., Faaij, A., & Van Vuuren, D. P. (2017). **Greenhouse gas emission curves for advanced biofuel supply chains**. *Nature Climate Change*, 7(12), 920-924.