Assessing the efficiency of changes in land use for mitigating climate change

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Extending the boundaries of environmental assessments: coupling Life Cycle Assessment with economic modelling

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Land use change and GHG emissions

- Evaluation of biofuel policy support
- Attributional life cycle analysis (LCA) does not take into account the emissions associated to land use change (LUC)
- Clearing of vegetation → direct LUC. Reallocation of uses → indirect LUC
- Economic model assess LUC (Searchinger et al. 2008, Hertel et al 2010)
  - Direct LUC. Indirect LUC with yield, area and demand effects (price and trade effects)
  - Decomposition of effects in Hertel et al 2010, Brunelle et al 2018
  - Wide range of results, in particular because of yield effects
  - Economic modelling not restricted to biofuel and GHG, for example Desquilbet et al 2017 on intensification levels and biodiversity
- Consequential LCA
  - When there is no direct land use change, increase the scope, in general to include import from a country with direct land-use change (Escobar et al 2014 , Styles et al 2017)
- Indirect land use change is still controversial

Opportunity of land use

- LCA per unit of area without LUC emissions implies the lowest possible production → maximizes land use
- With direct LUC only different results with and without current natural vegetation replacement → inconsistency
- LCA per unit of product without LUC emissions consider that locations with different foregone environmental benefits are equivalent, for example a crop in a desert and in an equatorial climate

- Economic models integrate the opportunity of land use, but
  - Comparisons are not based on environmental performance
  - Price effects are unintended consequences of land use change

Land uses efficiency indices

- General approach for comparison of agricultural GHG emissions
- Separation of demand and production
  - Production: avoid emissions elsewhere, a carbon benefit
  - Demand: require emissions, a carbon cost
- Control for other effects of GHG emissions change (no price effects)
  - Production and demand: constant yield
  - Production: unchanged global demand
- Give a carbon value to every location and production
  - Separating direct and indirect effects
- Production of biofuel compared to fossil fuel reference

Indirect and direct emissions

- Averaged coefficients for indirect emissions, assuming current production locations (fixed trade structure)
  - COC (cost of carbon): aggregate time discounted CO2 loss from native vegetation on production locations divided by discounted production (including pasturelands)
    - Alternatively consider reforestation and use the fraction of net primary productivity sequestered per unit of crop production
  - Average PEM (production emissions) per unit or production: nitrogen balance, tier 1 and tier 2 factors, livestock from GLEAM
- local PEM and carbon storage change emissions separately evaluated

Production carbon benefit

$$CB = COC_s + PEM_{bfits} + CARBST_{ch} + FOS_{sav}$$

$$COC_s = Y * COC$$
$$PEM_{bfits} = Y * \left(PEM_{avg} - PEM_h\right)$$
$$CARBST_{ch} = \frac{PDV_{cs\_ch}}{PDV}$$
$$FOS_{sav} = \left(BIOFY * (FOSEF - BIOFEF)\right)$$

- COC: cost of carbon
- PEM: production emissions
- CARBST: carbon storage change
- FOS: biofuel energy substitution

- Y: yield, BIOFY: biofuel yield
- PDV: present discounted value, PDV_{cs_ch} of carbon change
- FOSEF: fossil emissions replaced, BIOFEF: transformation emissions

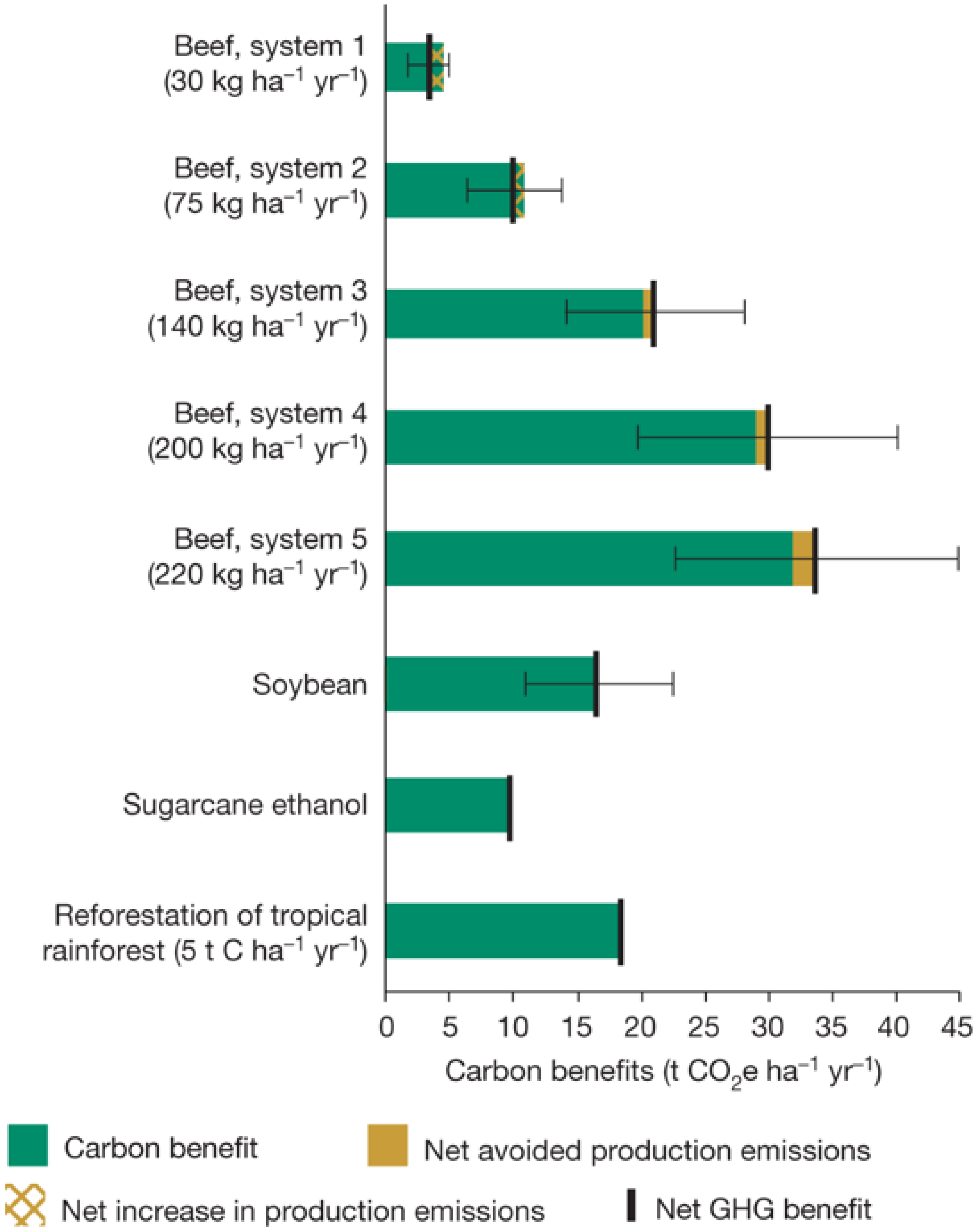
Demand carbon cost

- Assuming current production locations

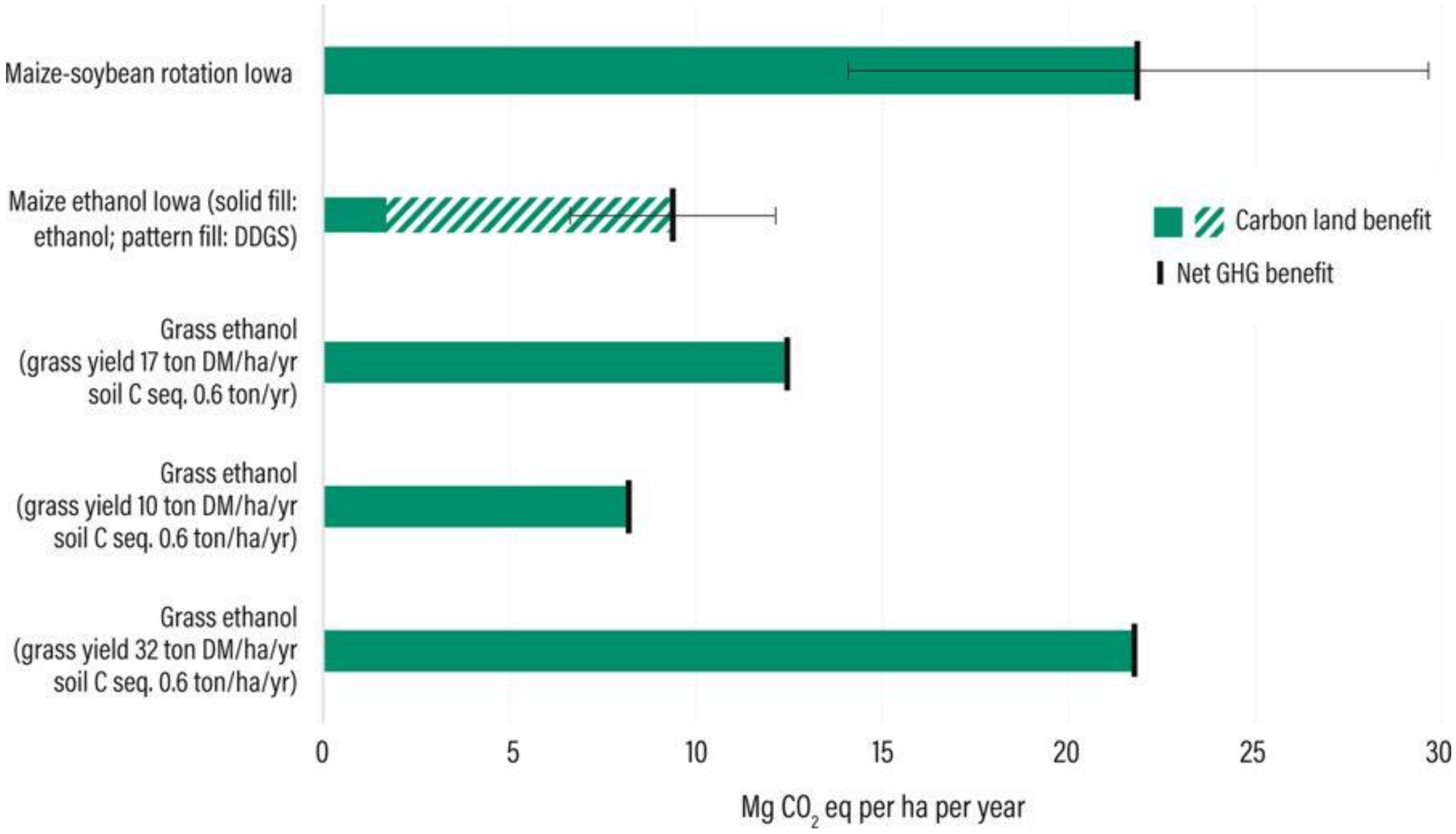
$$CCC = CONSUM * (COC + PEM)$$

Brazil cerrado

- Beef based on Cardoso et al 2016
- Sugarcane based on JEC LCA 2014

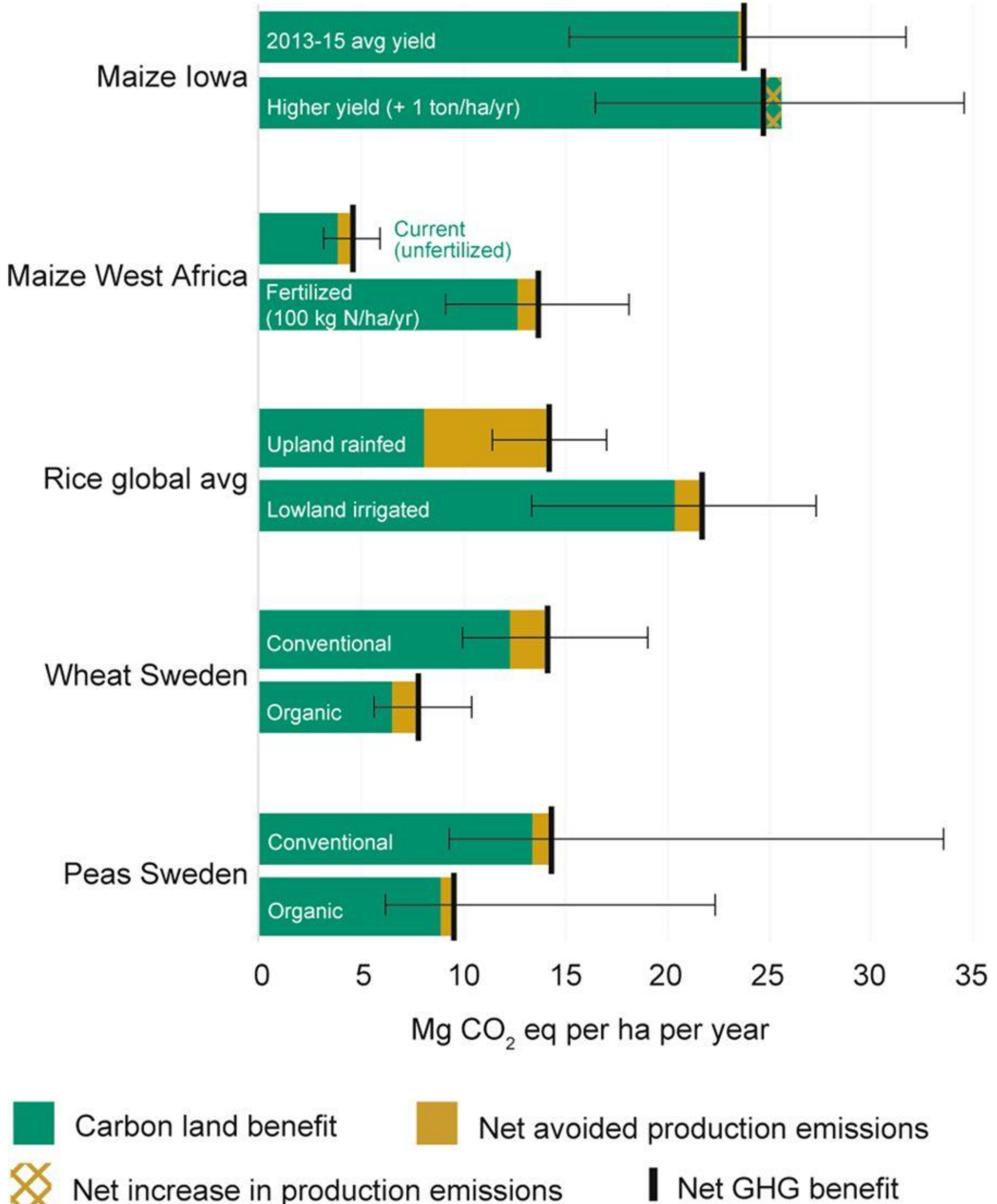


Iowa



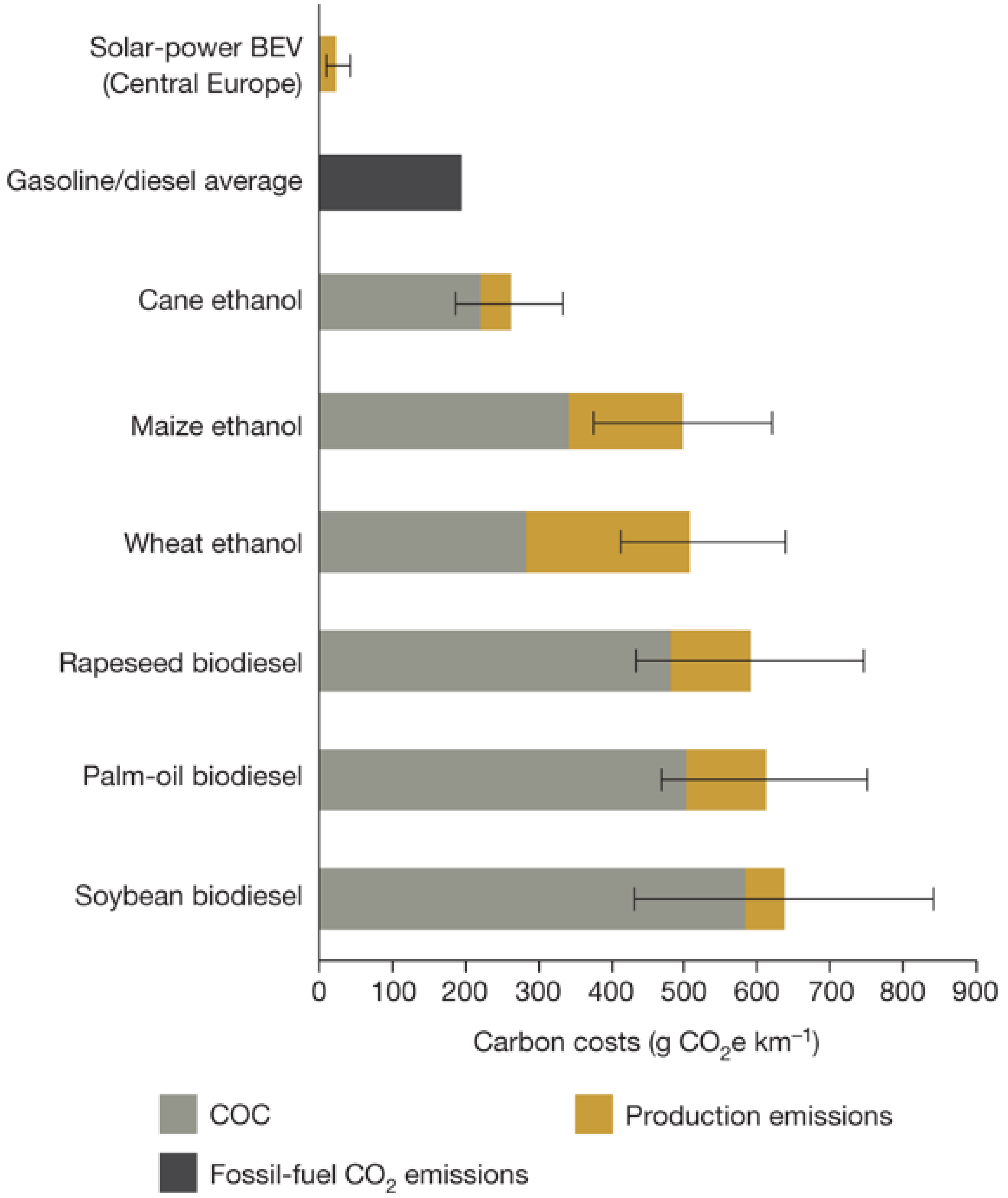
Maize-soybean rotation Iowa
Maize ethanol Iowa (solid fill: ethanol; pattern fill: DDGS)
Grass ethanol (grass yield 17 ton DM/ha/yr soil C seq. 0.6 ton/yr)
Grass ethanol (grass yield 10 ton DM/ha/yr soil C seq. 0.6 ton/ha/yr)
Grass ethanol (grass yield 32 ton DM/ha/yr soil C seq. 0.6 ton/ha/yr)
Carbon land benefit
Net GHG benefit
0
5
10
15
20
25
30
Mg CO2 eq per ha per year

Other comparisons



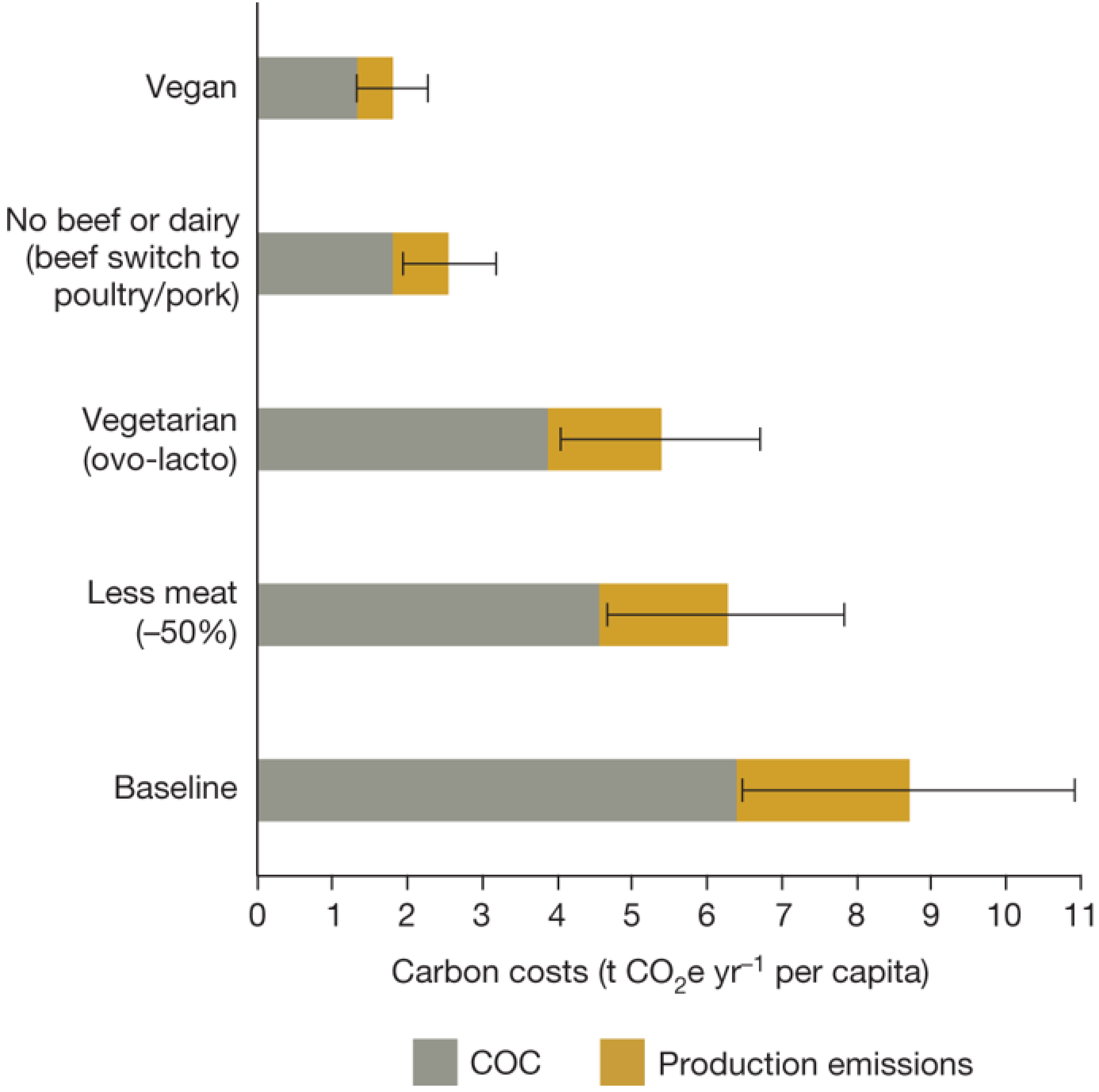
Biofuel emissions

- Using global average crop emissions, not current biofuel production location specific values



Diets comparison

- Using global average crop emissions



Discussion

- Error based on carbon stocks evaluation parameters
- Discounting: corresponds to opportunity of time and change in carbon price over time. Set to 2%, 4% and 6%, constant over 100 years
- COC and average PEM evolve over time
- Biodiversity, albedo, economic cost, effect on health (pesticides) not evaluated
- Implicit assumption of inclusion in markets. If not, the geographical coverage for COC and PEM calculation should be adjusted
- Equivalence with cost benefit analysis, with constant yield and fixed total demand. Need an equality of net costs or to add a cost difference and a carbon price to be exactly the same
- Use average for iLUC ≠ Marginal (Consequential LCA)

Use

- To help evaluate overall GHG emissions of changes in land use
  - Climate Smart Agriculture, 4 per 1000, development projects…
- As a factor in attributional LCA to include indirect emissions when production levels or type of product change
- To compare with economic model results equivalent factors and discuss the underlying hypotheses and effects intensities

- Cannot be compared to actual evolution
- Not directly adapted to the evaluation of actual policies, as demand and yields are not controlled, nor to study systemic changes

Reference

Timothy D. Searchinger, Stefan Wirsenius, Tim Beringer and Patrice Dumas. Assessing the efficiency of changes in land use for mitigating climate change. *Nature* **564**, 249–253 (2018). Doi: 10.1038/s41586-018-0757-z