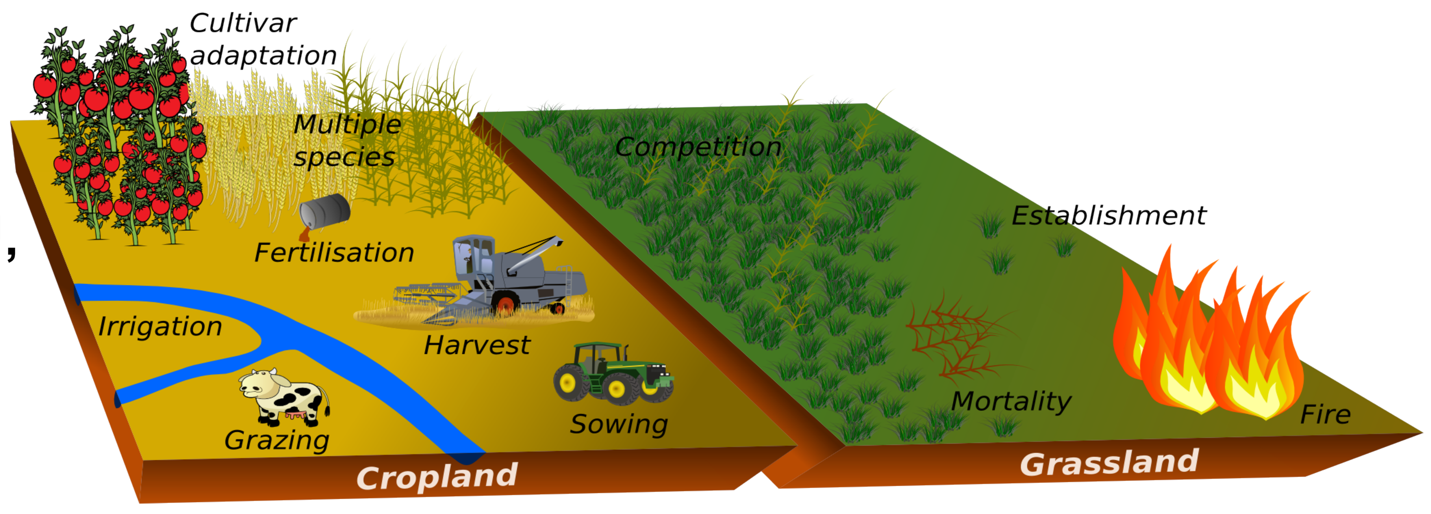
Carbon emission from land-use change is substantially enhanced by agricultural management



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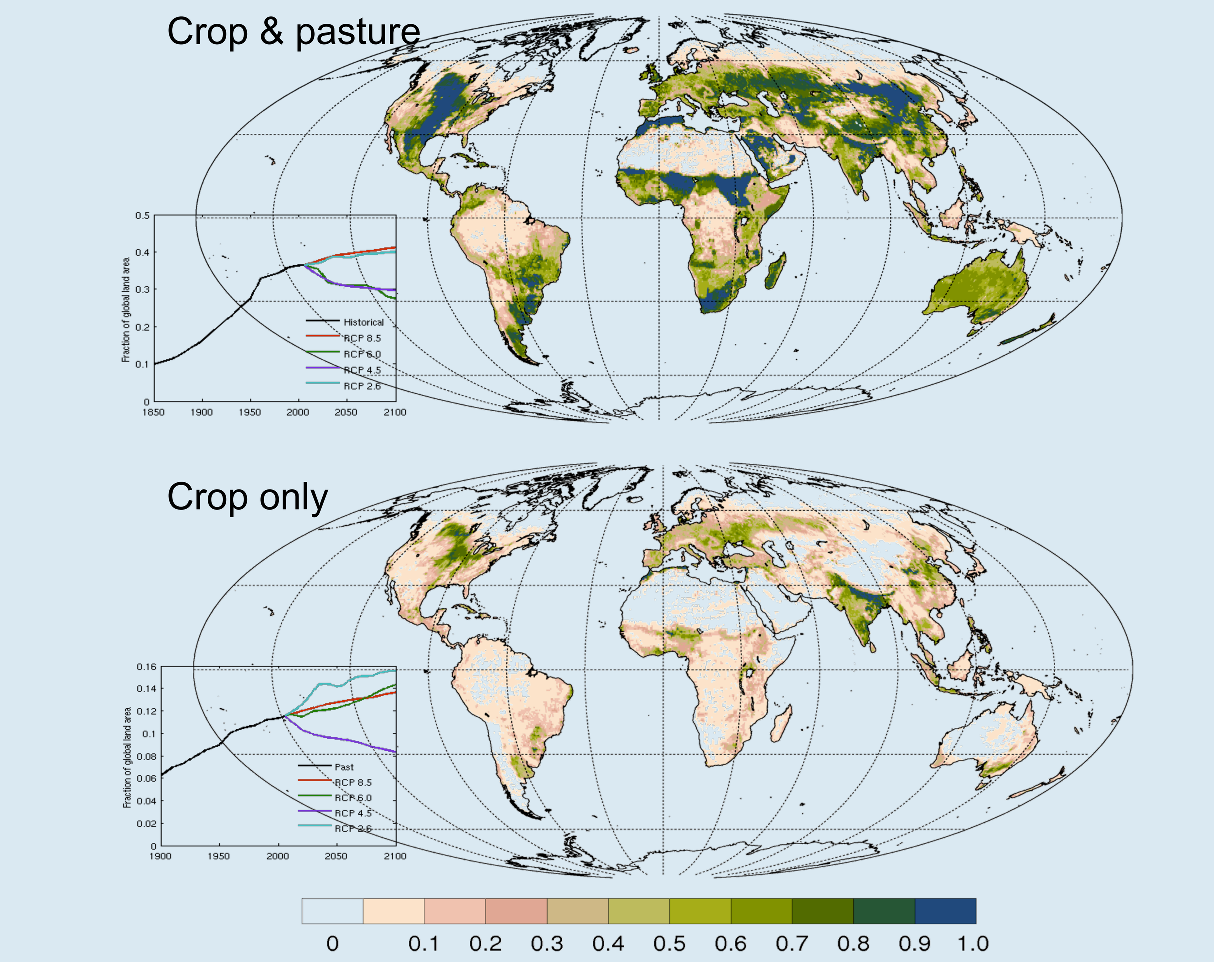
1. Motivation

- The terrestrial biosphere takes up about 1/3 of anthropogenic CO_2 emissions.
- Crops and pasture cover ~1/3 global land area (2005).
- Global climate models represent crops as simple grasses, ignoring physiological differences and management processes such as harvest, grazing, sowing and irrigation.

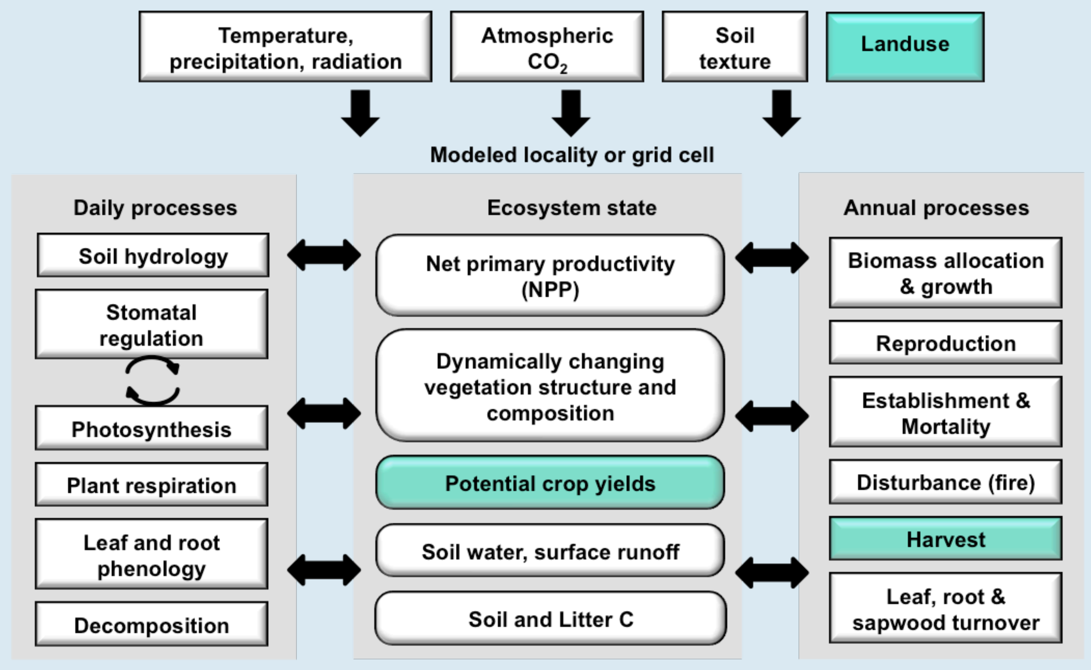
What is the effect of including a dedicated crop model in calculations of global land carbon uptake?



Fraction of global land area converted to agricultural use by 2005 (maps) and total areal change 1850-2100 (insets). Data from Hurtt et al. (2011).

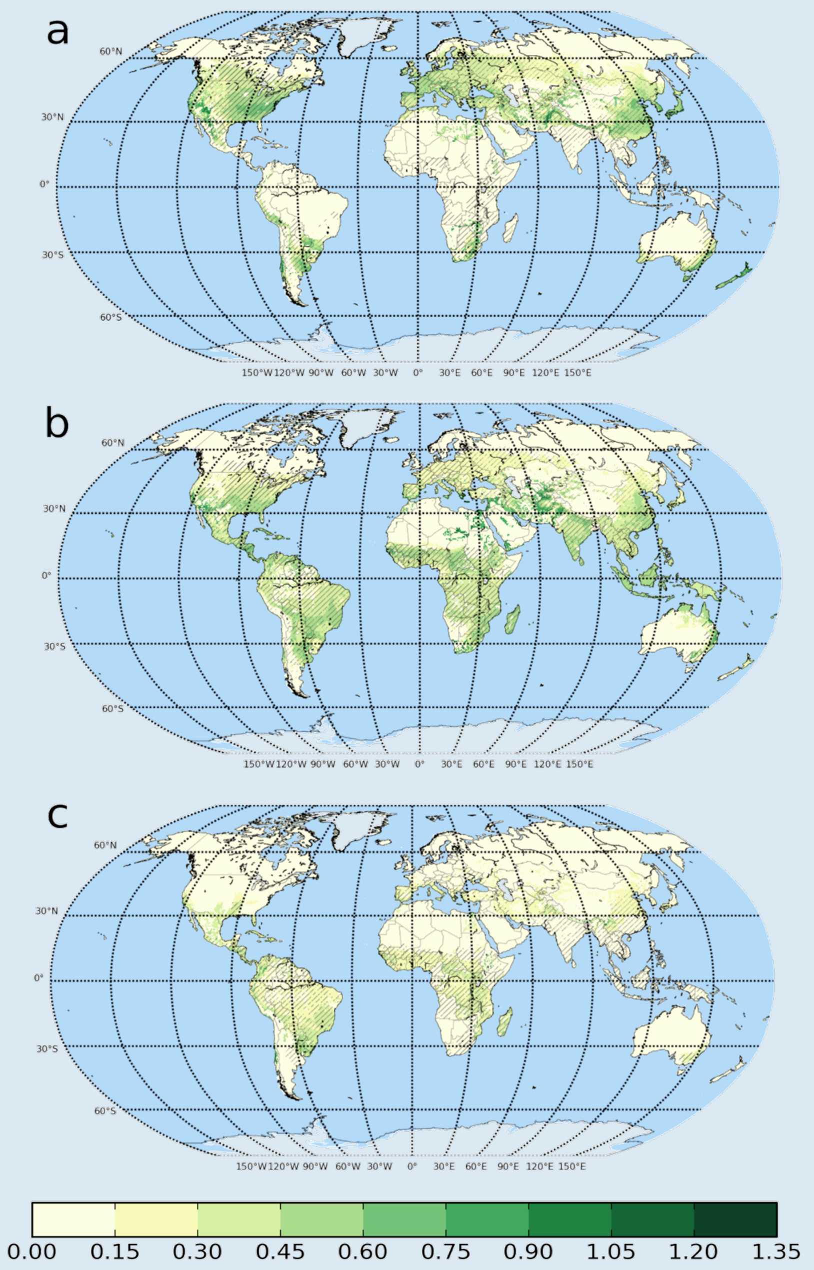
2. Methods

Global LPJ-GUESS dynamic vegetation model simulation (without interactive N) driven by forcings for RCP 8.5 from 6 different global climate models with Hurtt et al. (2011) land-cover data.



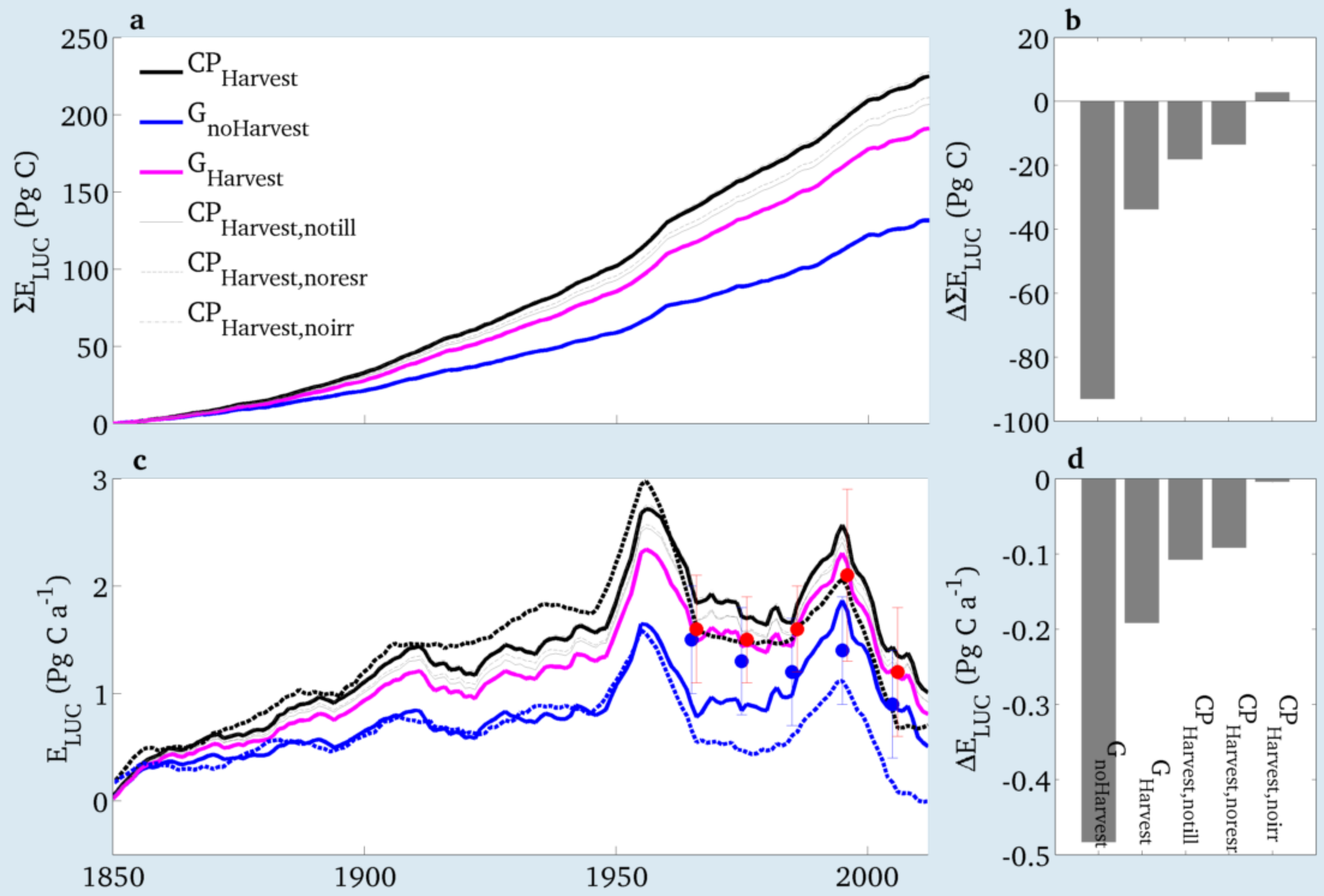
Net biospheric exchange of carbon from different simplified crop representations is compared with that from a detailed crop model with 13 crop types and specialised processes (Lindeskog et al., 2013).

3. How good is the model?



Modelled yields for wheat (a), maize (b) and rice (c) (kg dry weight m^{-2}). Hatching denotes model is within 1 σ of observations by FAO.

4. Results



Cumulative land-use change emissions since 1850 for simulations with **crops-as-grasses**, **crops-as-grasses with harvest/grazing** and **detailed crops** (grey lines show effects of various management options). Bar chart shows difference relative to detailed crops for 2012.

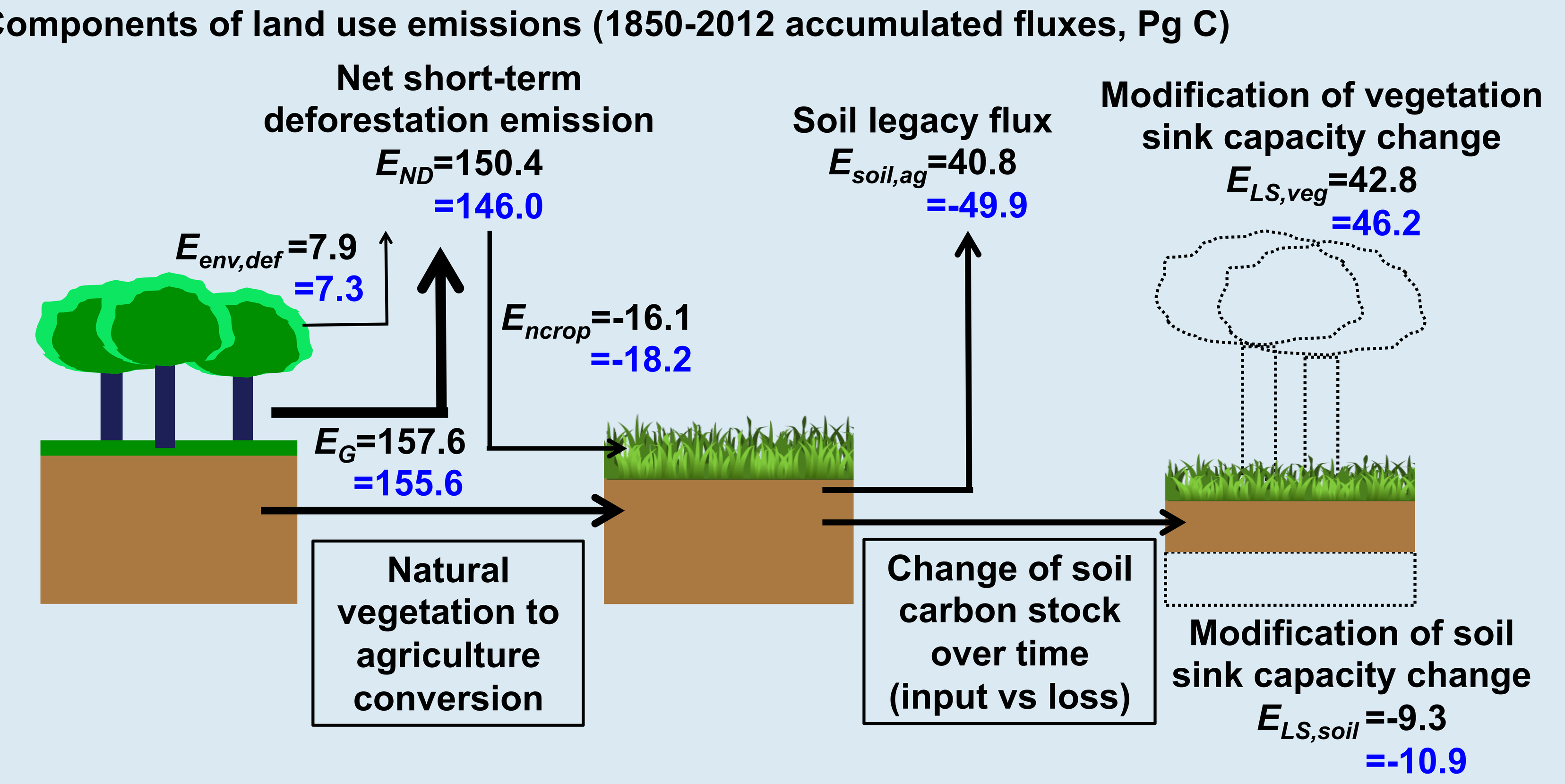
Annual land-use change emissions. Blue dots show budget estimates from Le Quéré et al. (2014) and red dots the mean of the DGVM ensemble from that study. Bar chart shows difference relative to detailed crops for 2003-2012 mean.

- 1850-2012 cumulative land-use change emissions are **225 Pg C** with detailed crops, but **130 Pg C** with crops-as-grasses (as used in most CMIP5 models).
- Difference in atmospheric CO_2 mixing ratio due to additional emission from agricultural processes can be 27 ppmv in 2012.

5. Why

Increased emissions of CO_2 are tied to re-equilibration of soil carbon stocks to changes in inputs (primarily harvest) and soil respiration rates. Most emissions occur in the decades immediately following a land-use or management change.

Components of land use emissions (1850-2012 accumulated fluxes, Pg C)



6. Conclusions

Inclusion of key agricultural processes in a global vegetation model increases land-use change emissions by up to 1 Pg C a^{-1} over 1850-2012.

This implies that models which neglect agricultural processes overestimate the net terrestrial carbon sink or underestimate the size of individual uptake mechanisms.

- Representations of harvest/grazing and soil respiration rates have the biggest potential to affect global terrestrial carbon uptake.
- Management processes influencing crop productivity *per se* (e.g. irrigation) are important for food supply, but had little influence on land use change emissions. Crop productivity is not a key factor for the global carbon cycle over periods of more than one year.

References.
Hurtt et al. (2011) *Climatic Change* **109**, 117–161.
Lindeskog et al. (2013) *Earth Syst. Dynam.*, **4**, 385-407.
Le Quéré et al. (2014) *Earth Syst. Sci. Data*, **6**, 235-263.