Managed land and the climate system: Is the representation in Earth-System Models sufficient?

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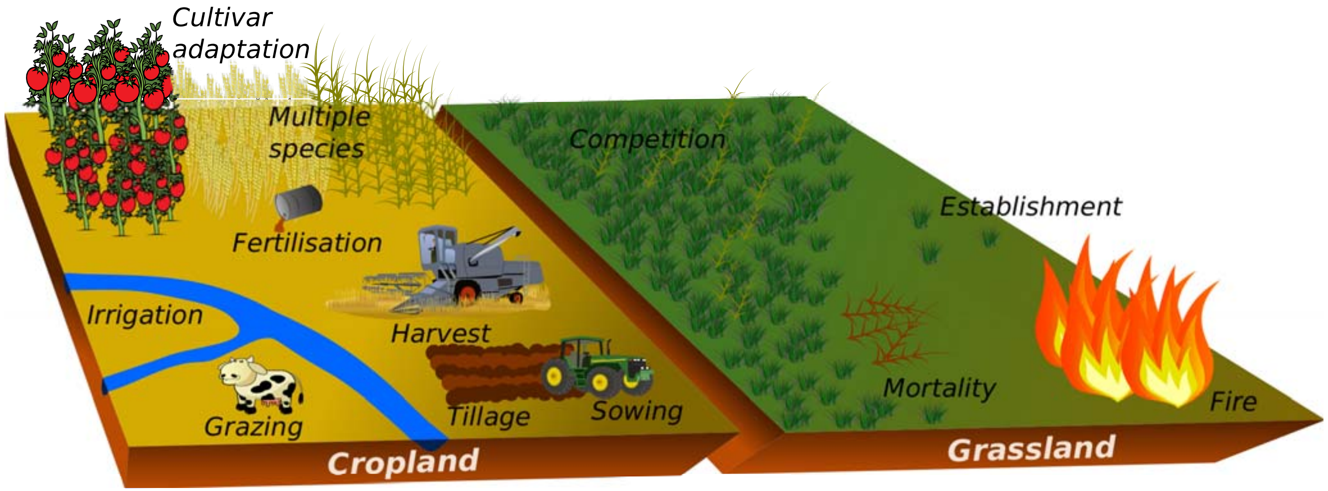
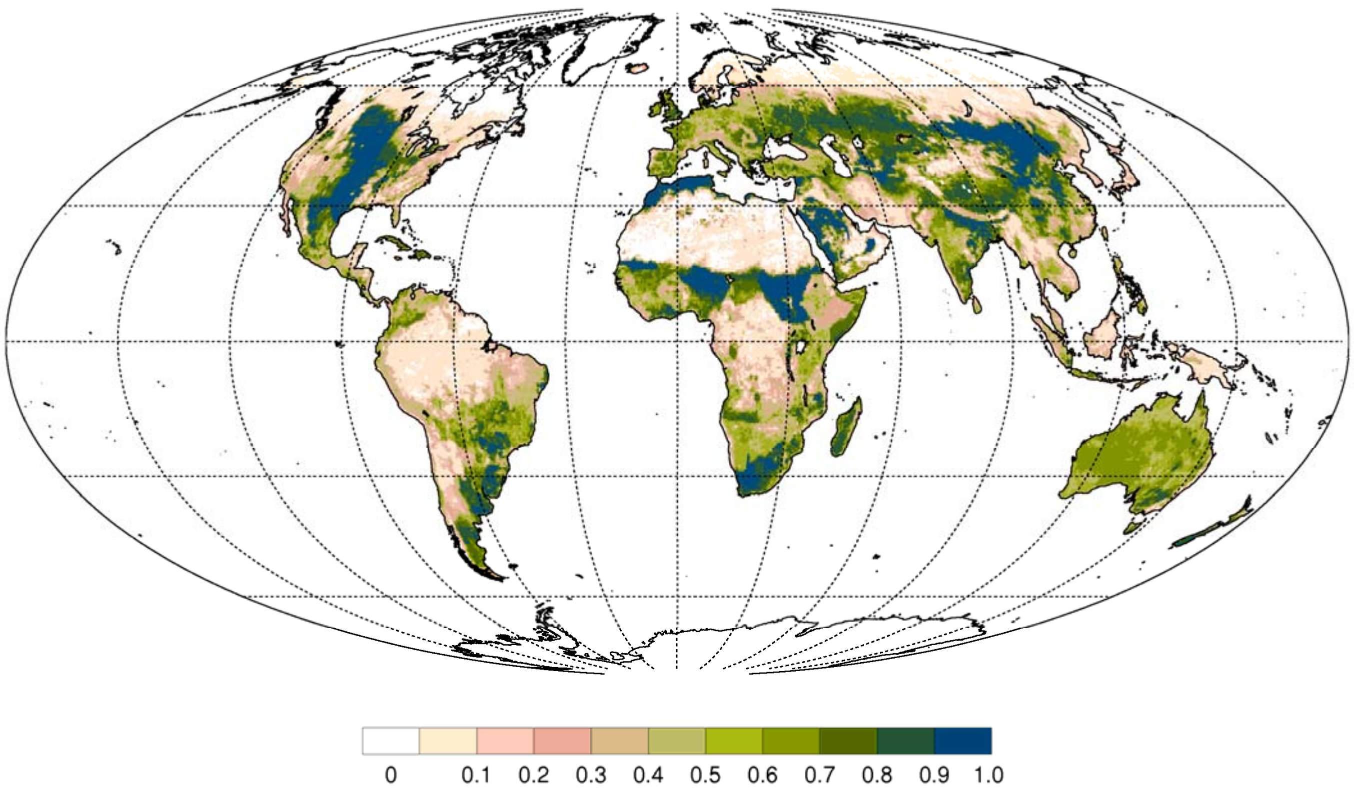
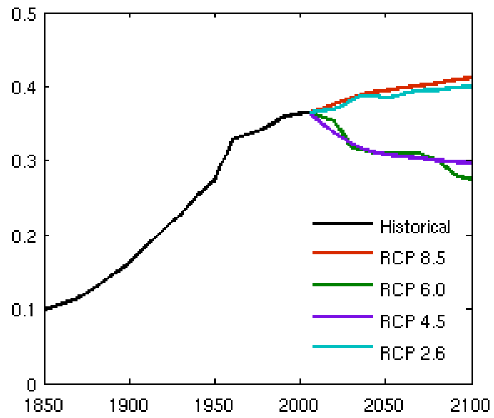


2nd GLP Open Science Meeting, Berlin, March 2014

Quick history of land-cover change and global climate modelling



Estimated crop and pasture cover fraction in 2005.



- IPCC AR4 Global Climate Model simulations ignored land-cover change.
- AR5 GCM simulations included simple representations of land-cover change.

Figures based on Hurtt et al.,Climatic Change, 2011.

Quick history of land-cover change and global climate modelling

But the uncertainty in land-use emission magnitude is huge.
There are no direct global measurement constraints.

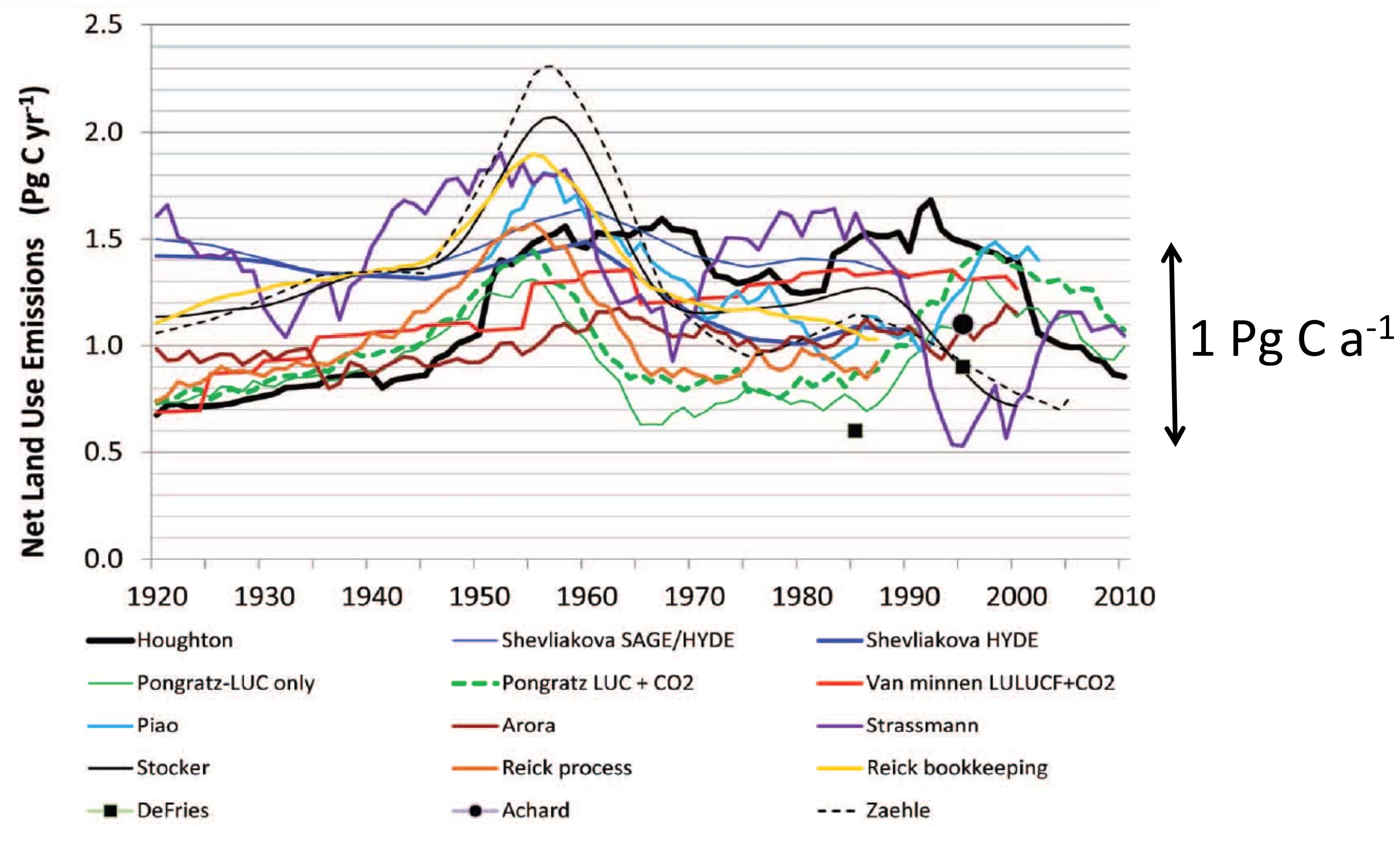


Figure from Houghton et al. Biogeosciences, 2012.

Quick history of land-cover change and global climate modelling

Differences in ESM terrestrial carbon storage between simulations with and without land-cover change can be very large.

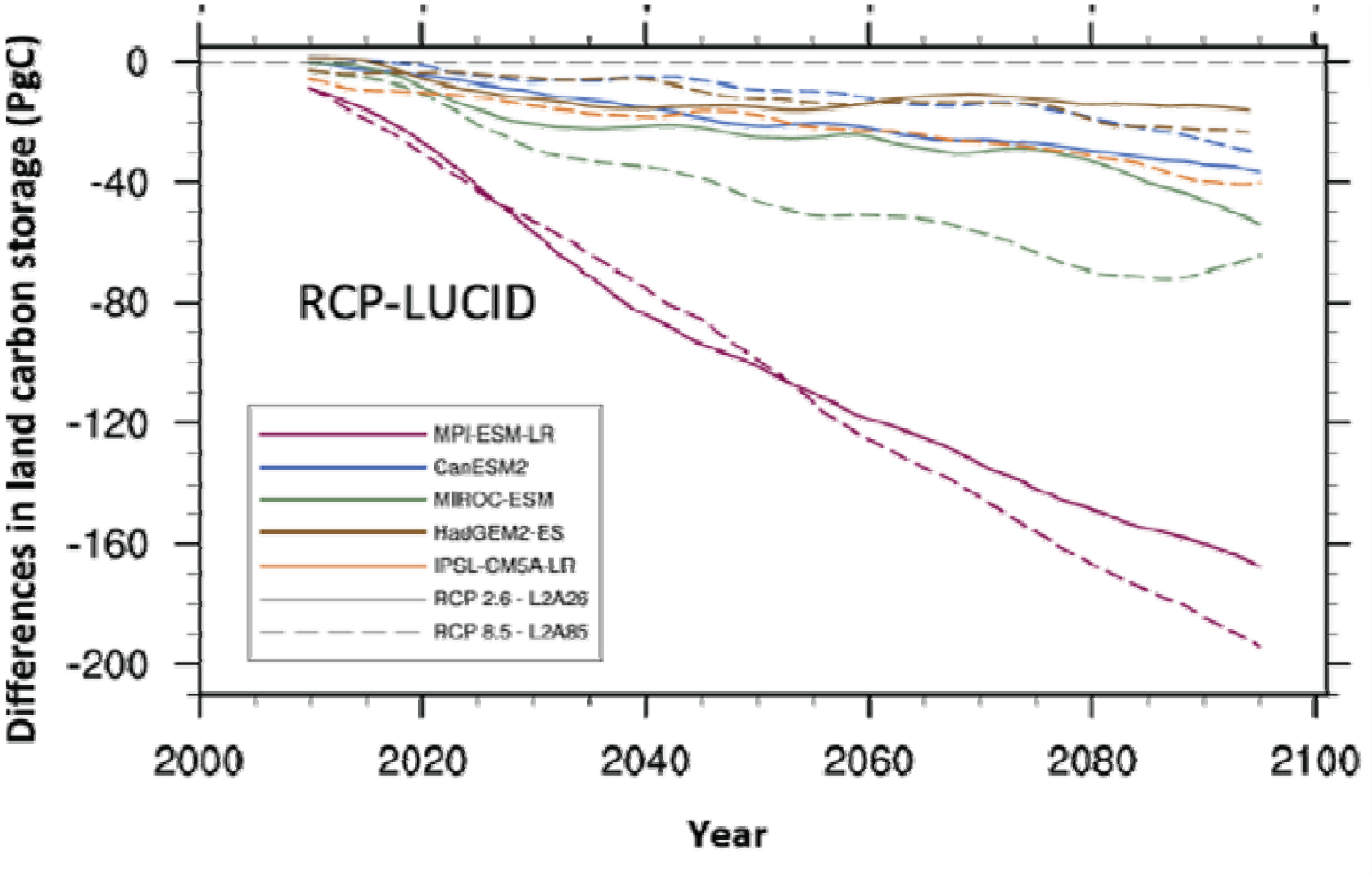
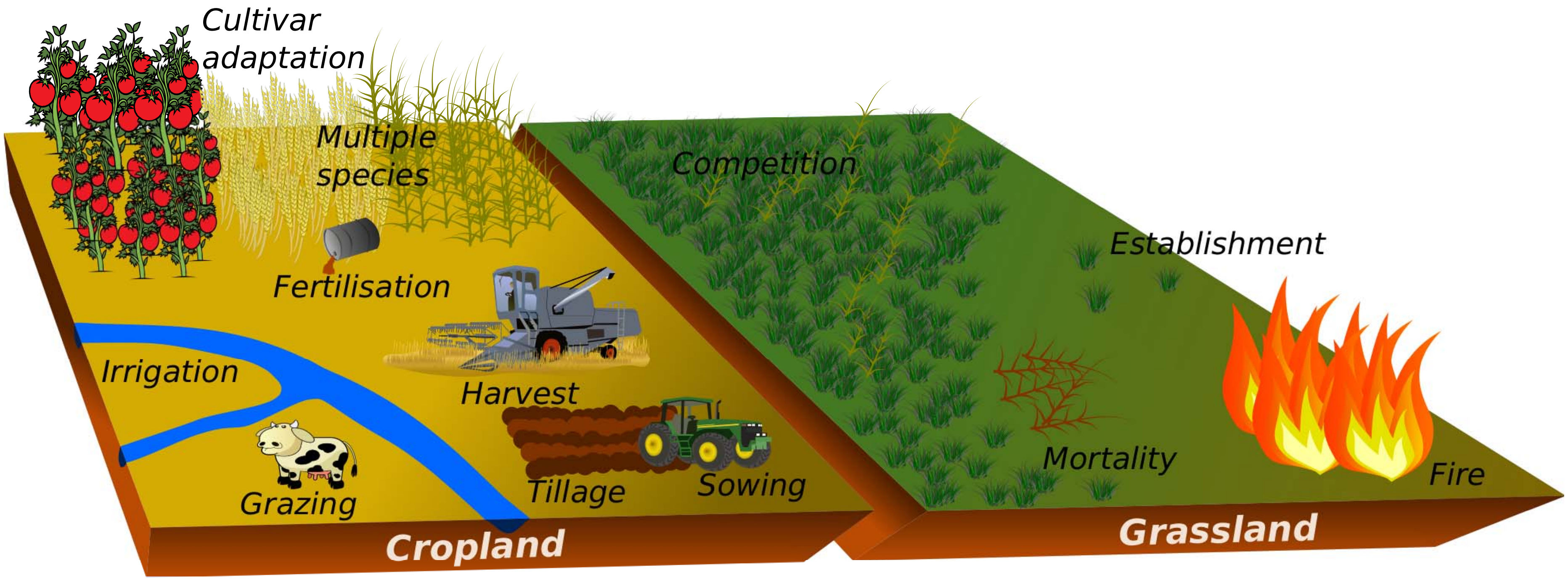


Figure from Brovkin et al. Journal of Climate, 2013.

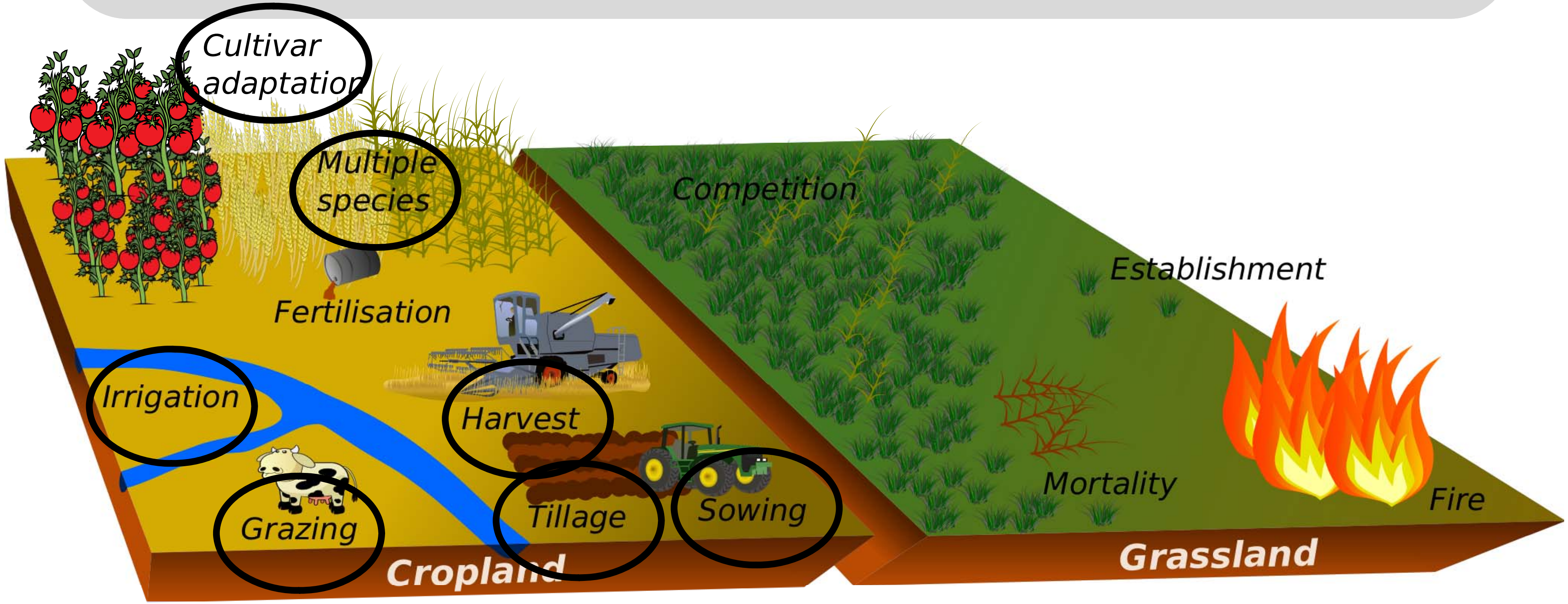
How much does agricultural representation affect the carbon cycle?

- AR5 ESMs and many DGVMs represented croplands as grasslands, broadly excluding the specific features of managed systems.
- However, in reality croplands (and to a lesser extent pasture lands) are very different from natural grassland ecosystems.



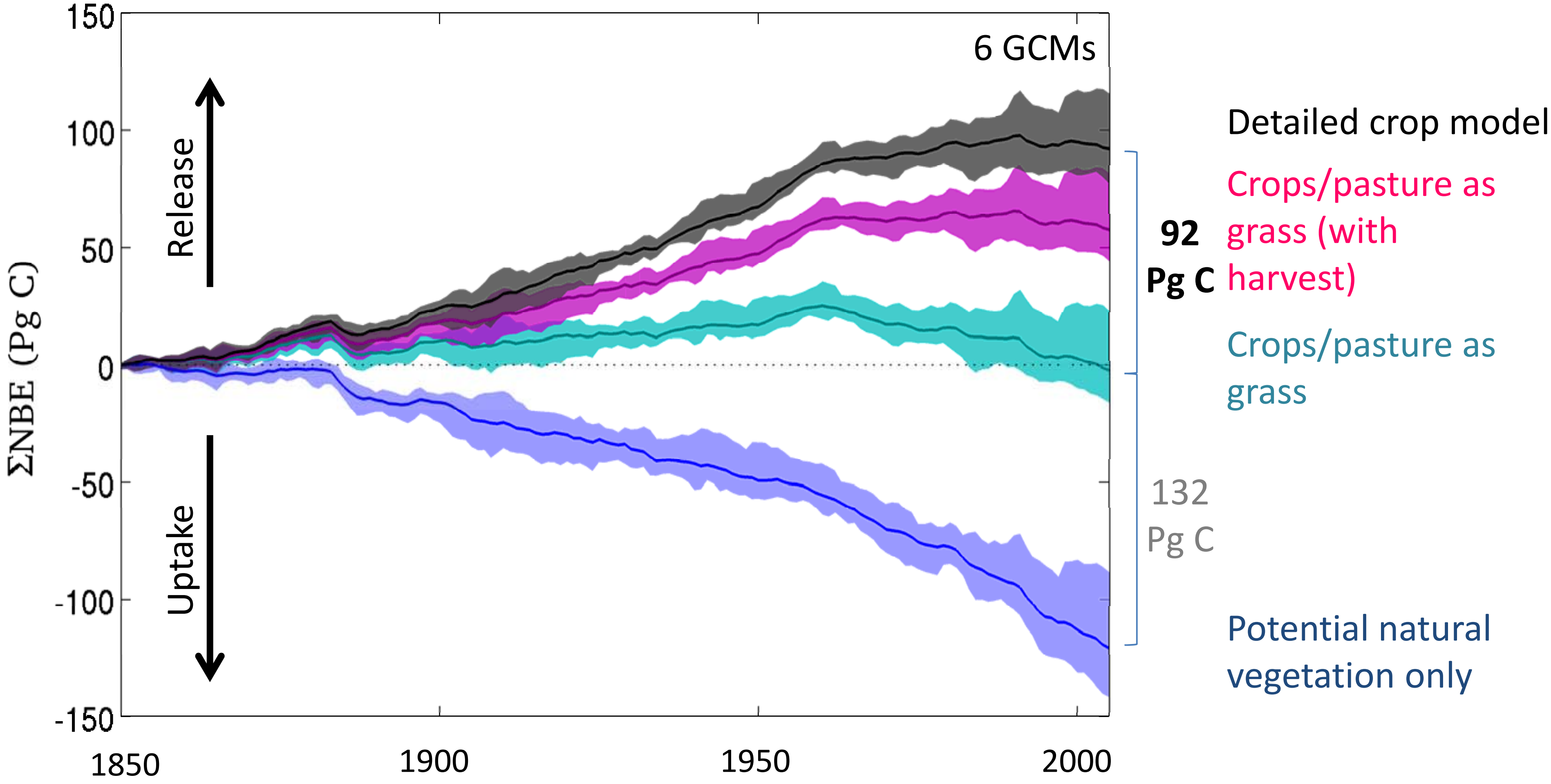
How much does agricultural representation affect the carbon cycle?

We used the LPJ-GUESS Dynamic Global Vegetation model with a detailed representation of agricultural processes (Lindeskog et al., Earth System Dynamics, 2013) to investigate how agricultural representation may affect the modelled land carbon sink.



How much does agricultural representation affect the carbon cycle?

Change in modelled terrestrial carbon uptake since 1850



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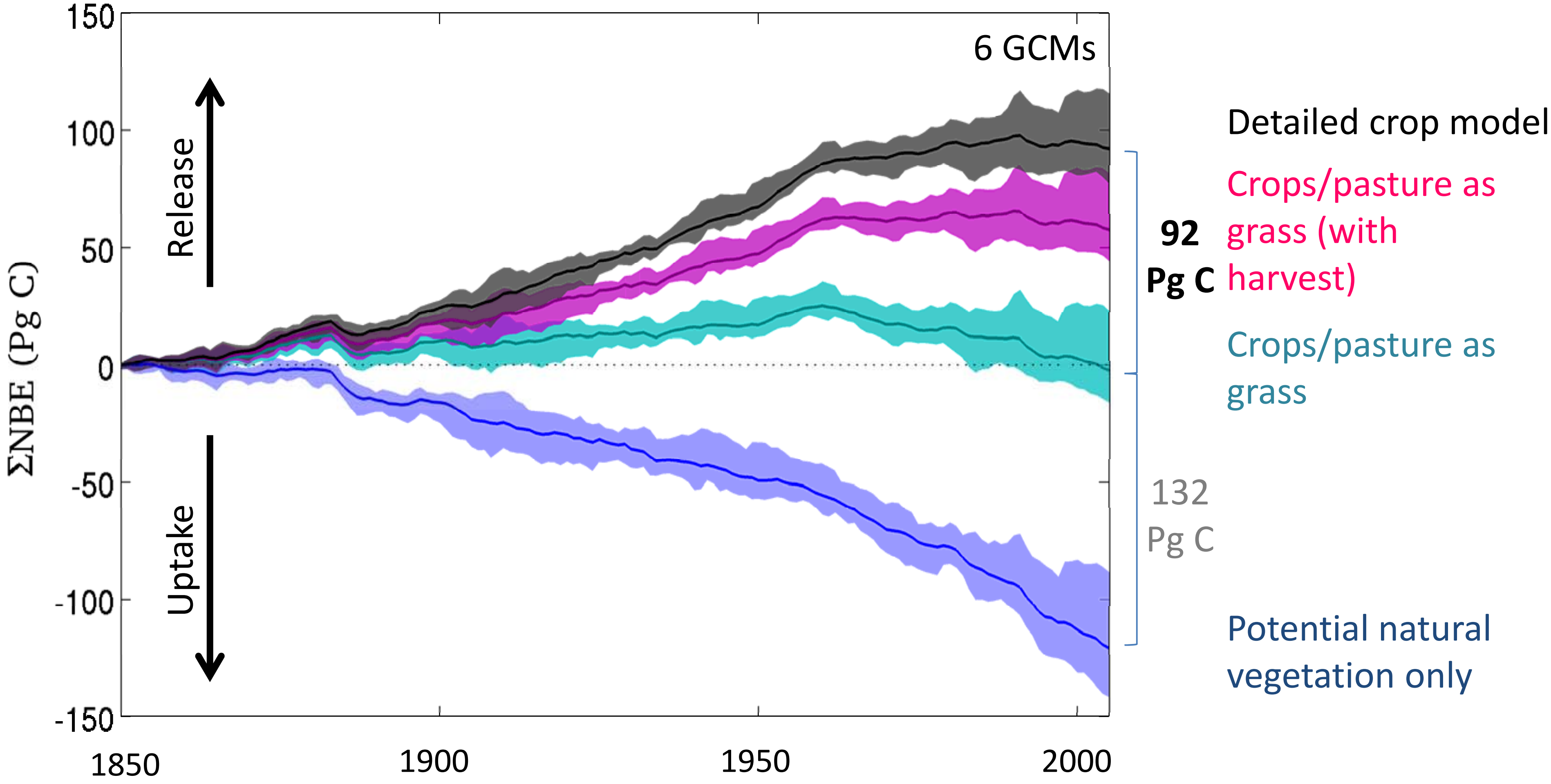
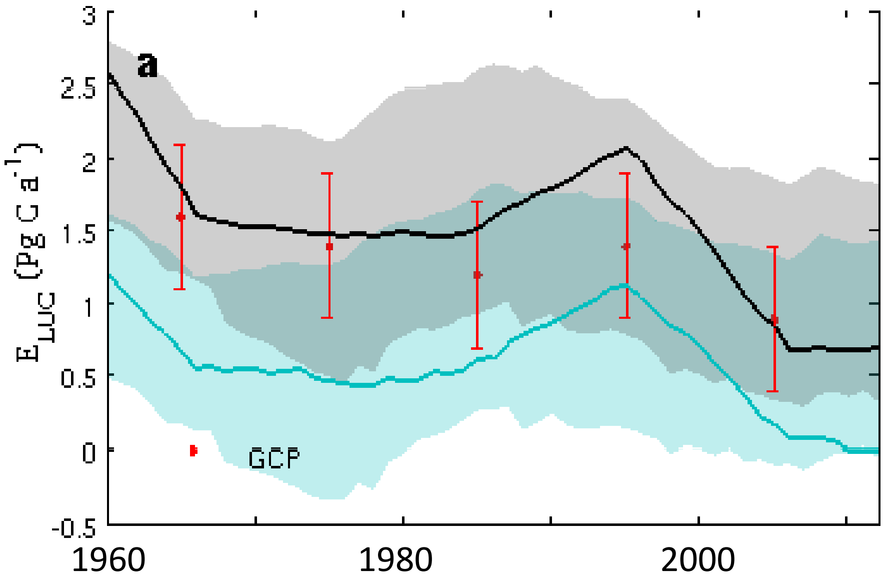


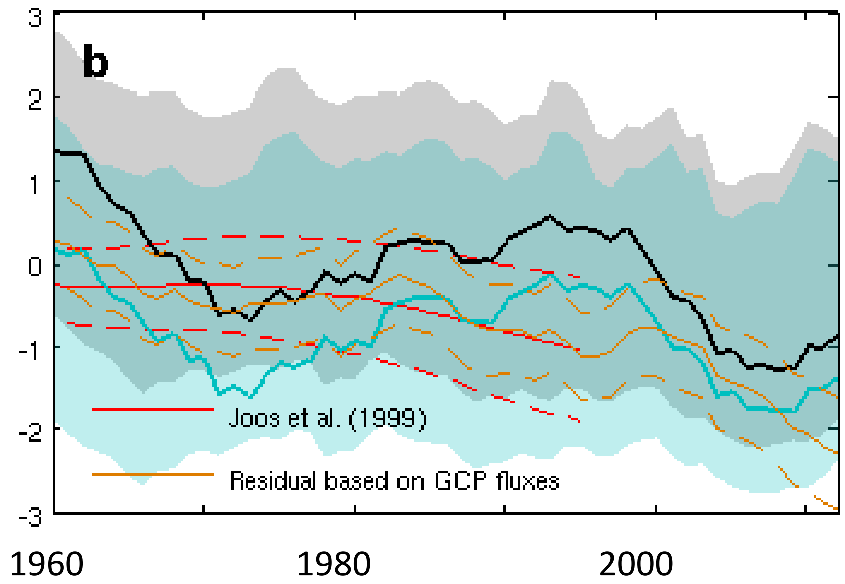
70% increase in overall LUC emissions

Comparison to other estimates

Land-use change emissions E_{LUC}

$$NBE = E_{LUC} + S_L$$

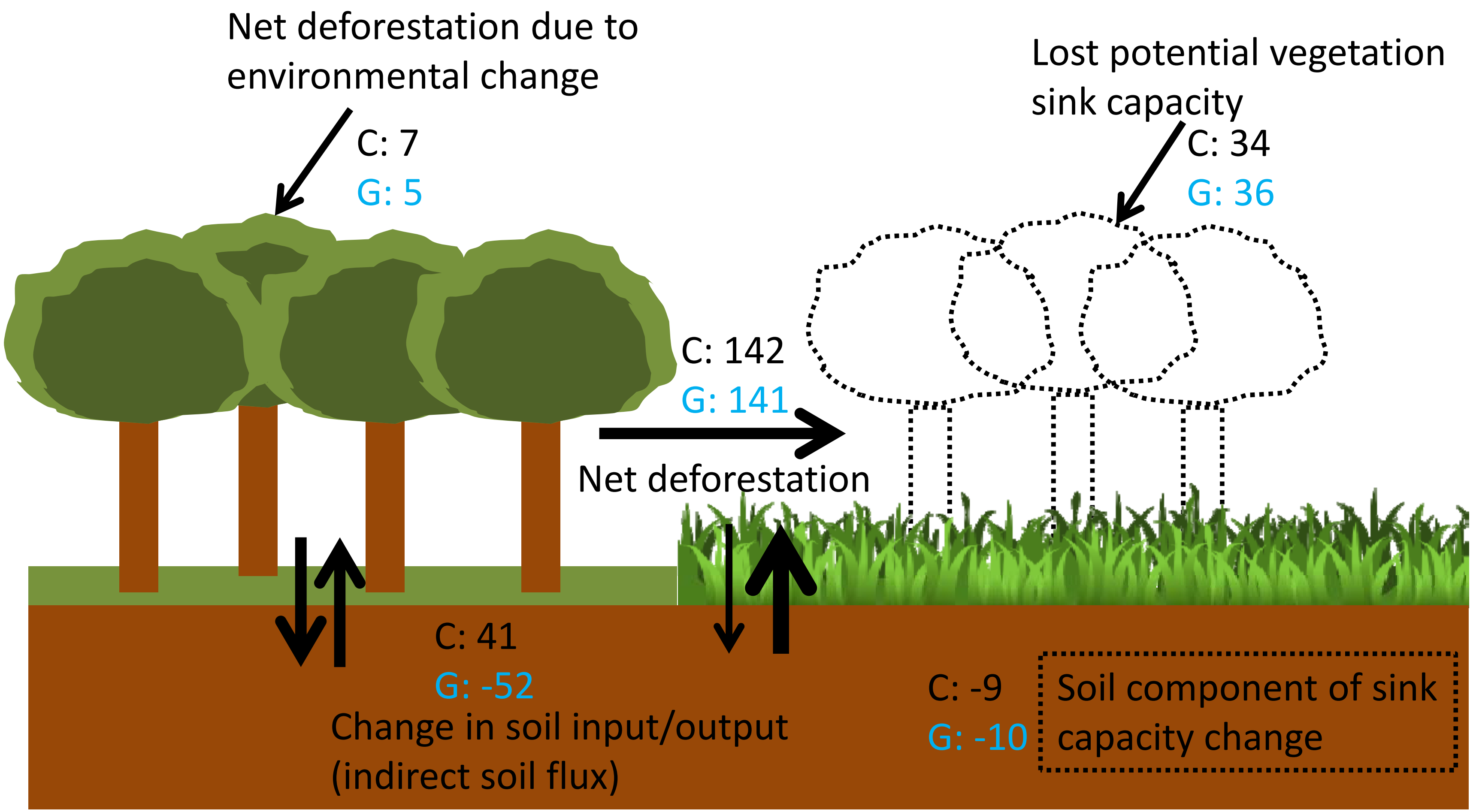




Why is the difference so large?

Components of LUC flux:

(1850-2012 accumulated fluxes,Pg C)



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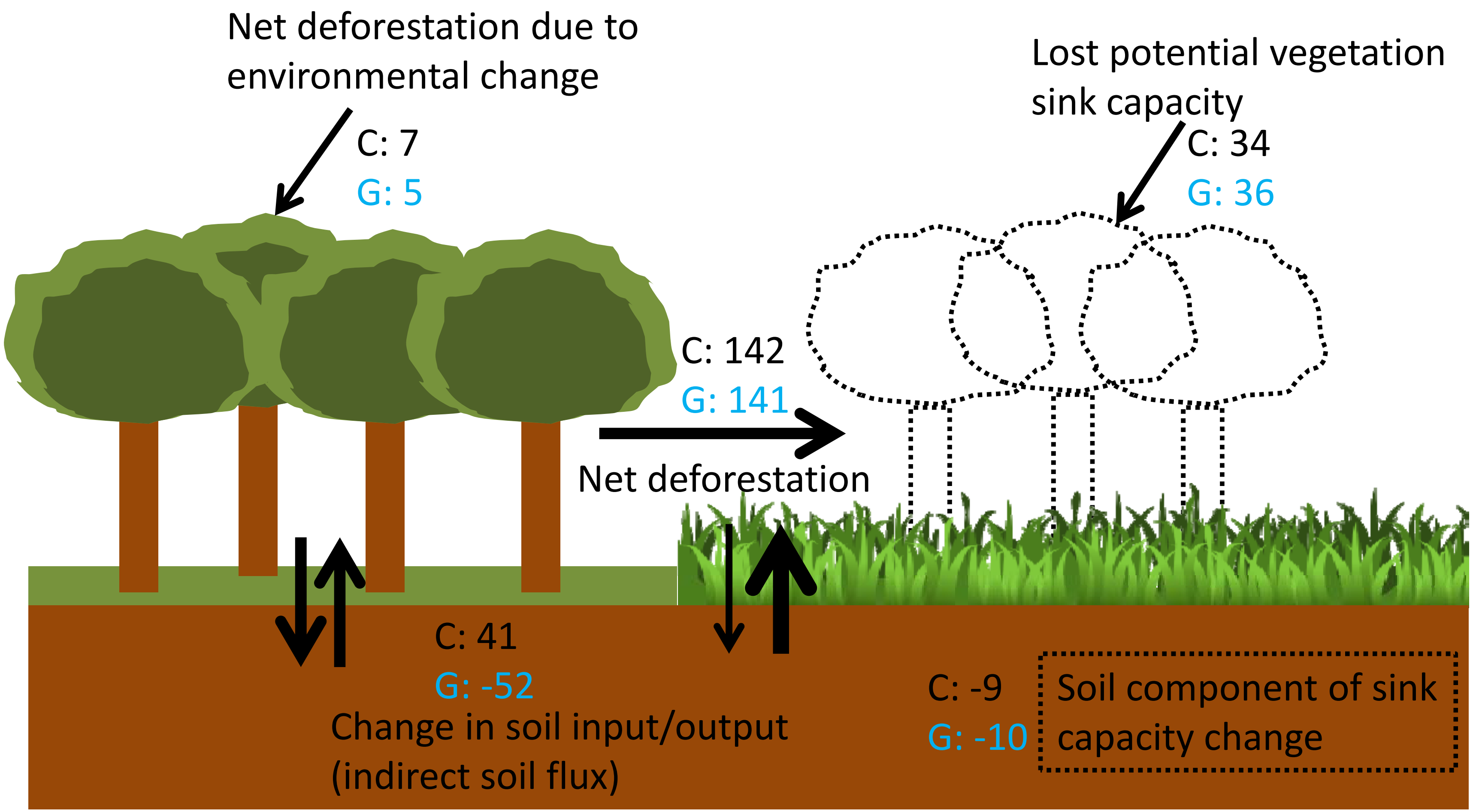
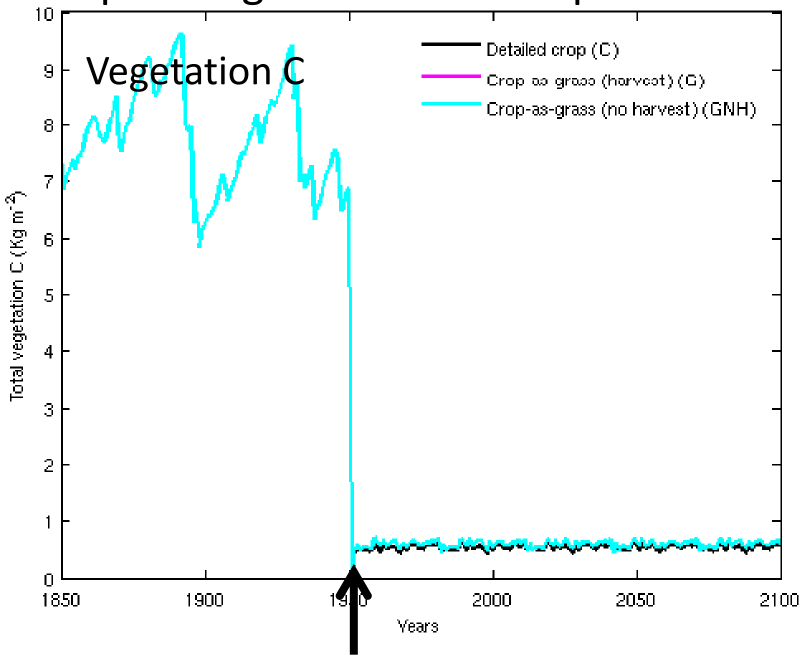


Harvest and tillage are the key processes

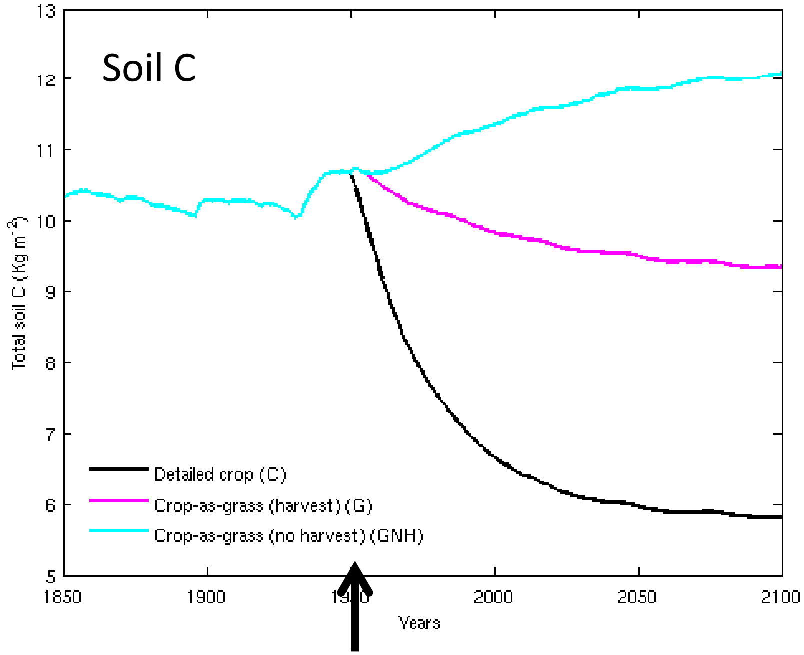
Why is the difference so large?

What is actually happening?

Example: Single site with complete conversion event at 1950.



Deforestation

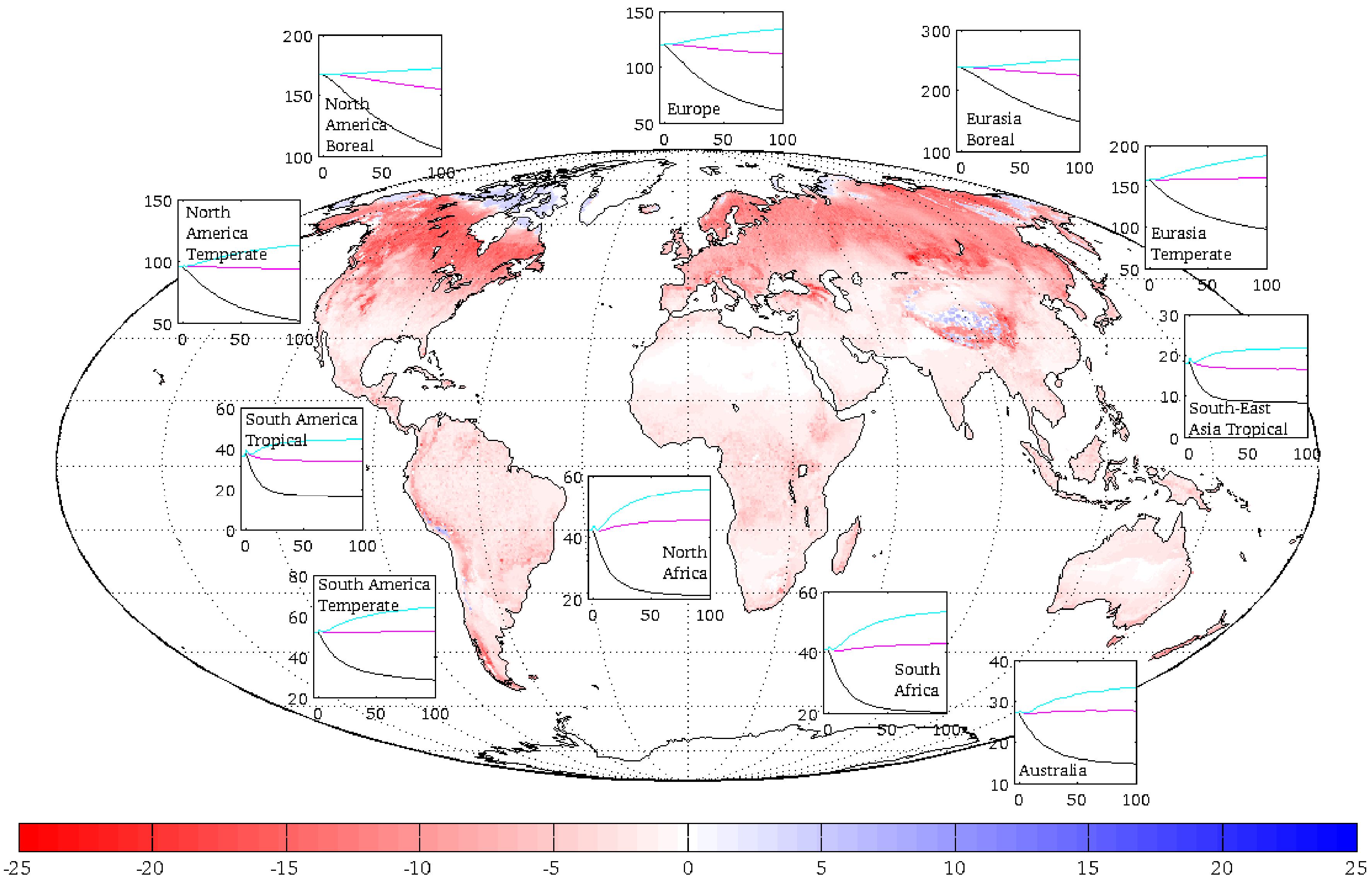


Deforestation

- Grassland actually accumulates more soil C than forest.
- But harvest results in “immediate” oxidation of C that would otherwise enter soil.
- Tillage gives higher soil respiration rates in cropland.
- C changes due to differences in productivity very small (due to harvest).

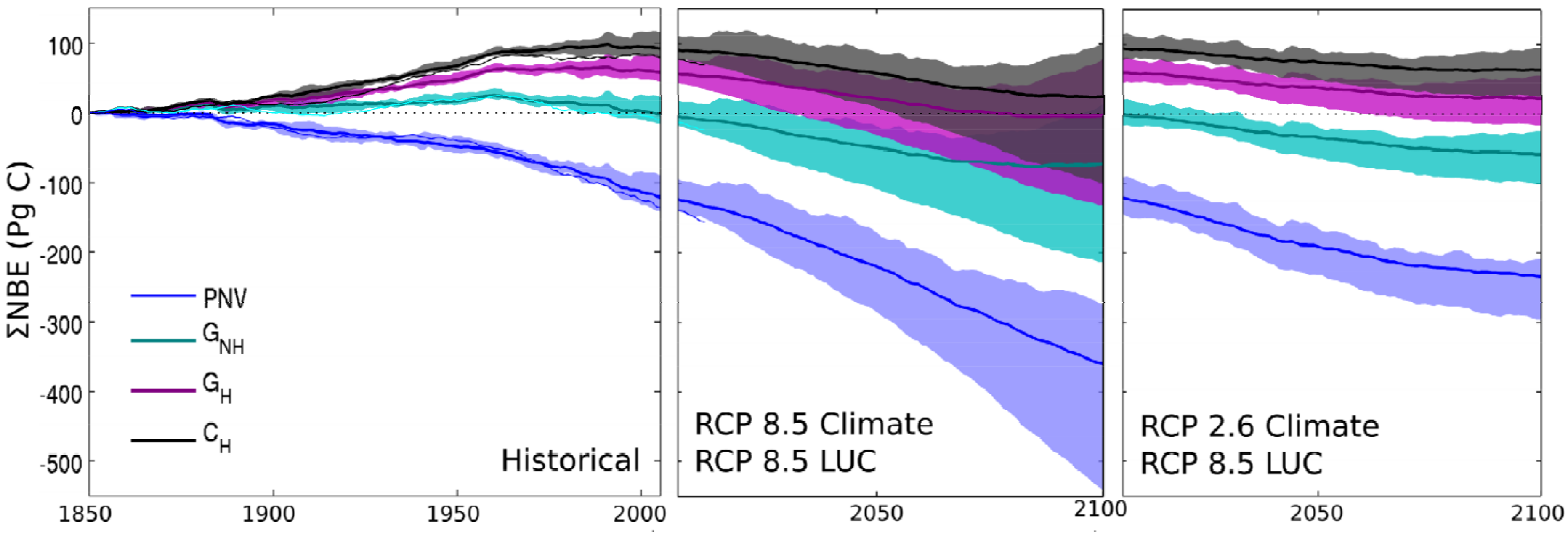
Why is the difference so large?

Change in soil carbon content upon conversion from natural to cropland (Kg C m^{-2})

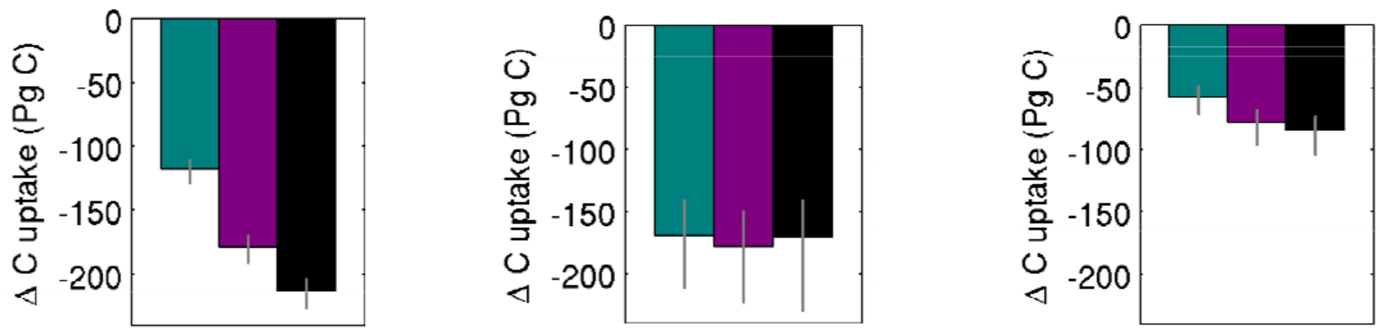


What about the future?

Extend simulations into the future using RCP scenarios



Change in
C uptake
relative to
PNV



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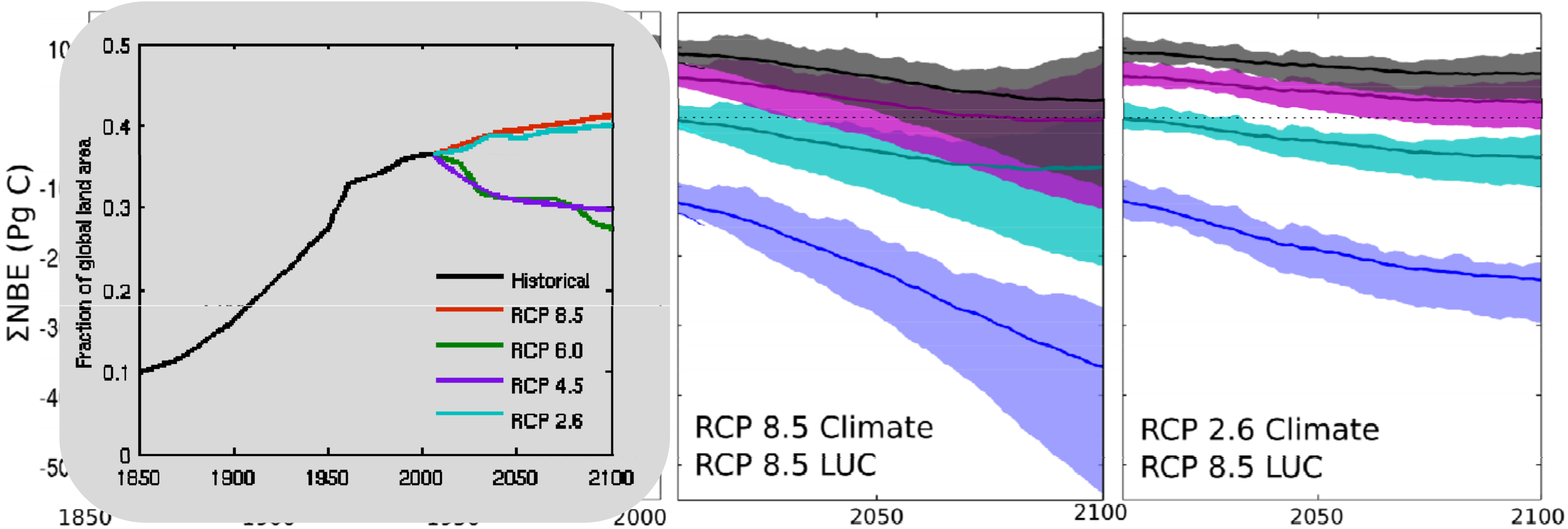

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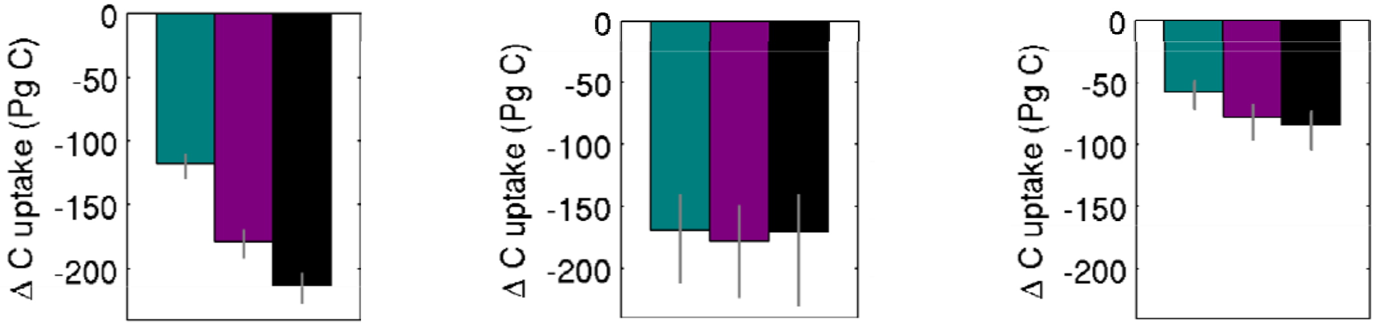

Summary

Agriculture-specific processes are not generally considered in AR5 ESMs.

Agricultural representation, especially harvest/grazing, can greatly influence the simulated terrestial carbon sink.

Effect of agriculture on carbon fluxes is tied to date of land-use transition, rather than an ongoing source.

Overall effect on radiative forcing can be of the order 0.5 W m^{-2} since pre-industrial.

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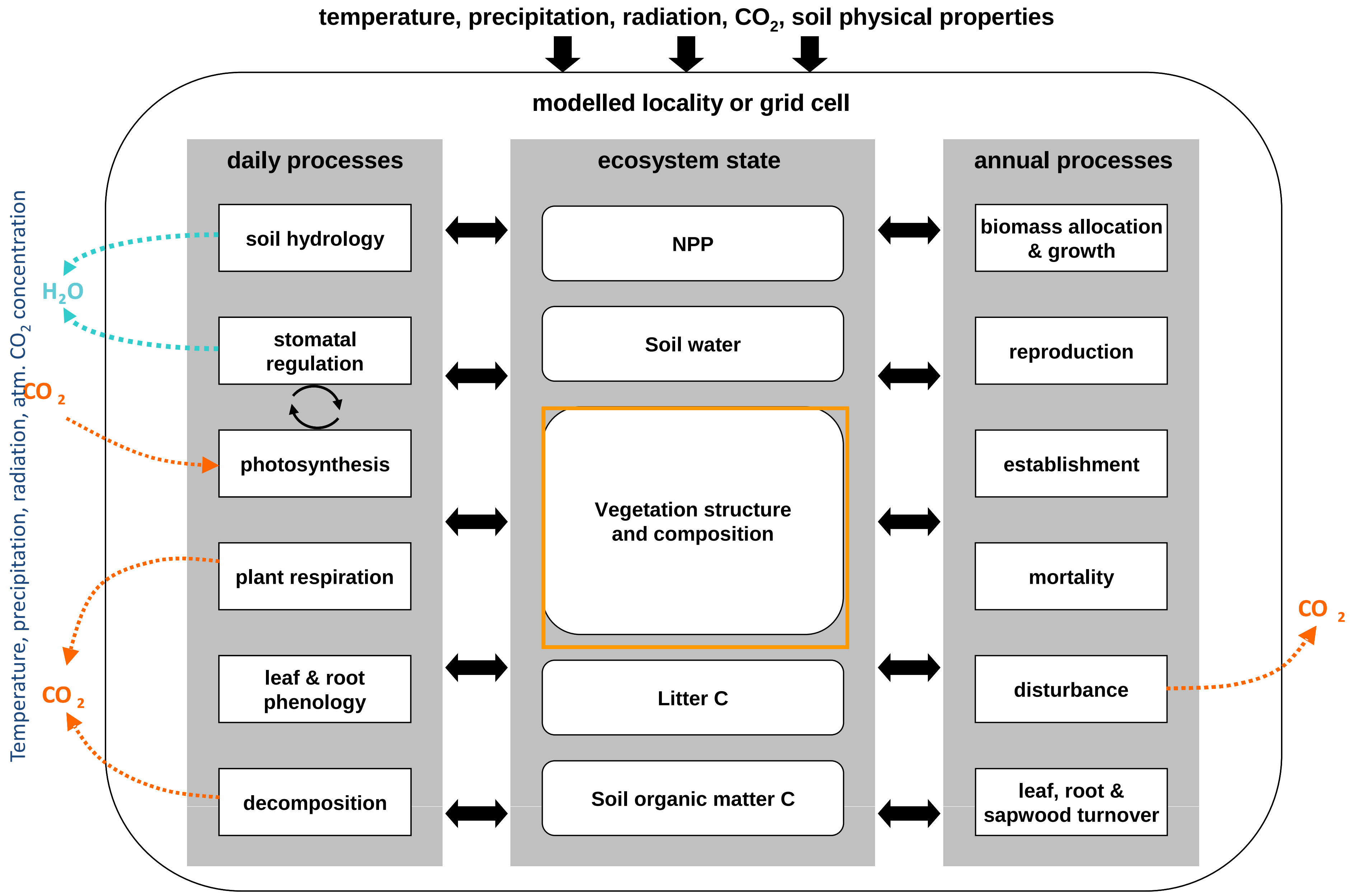
Overall effect on radiative forcing can be of the order 0.5 W m^{-2} since pre-industrial.

Must also consider biophysical effects and non-CO_2 greenhouse gases...


Cheers for listening!

LPJ-GUESS structure



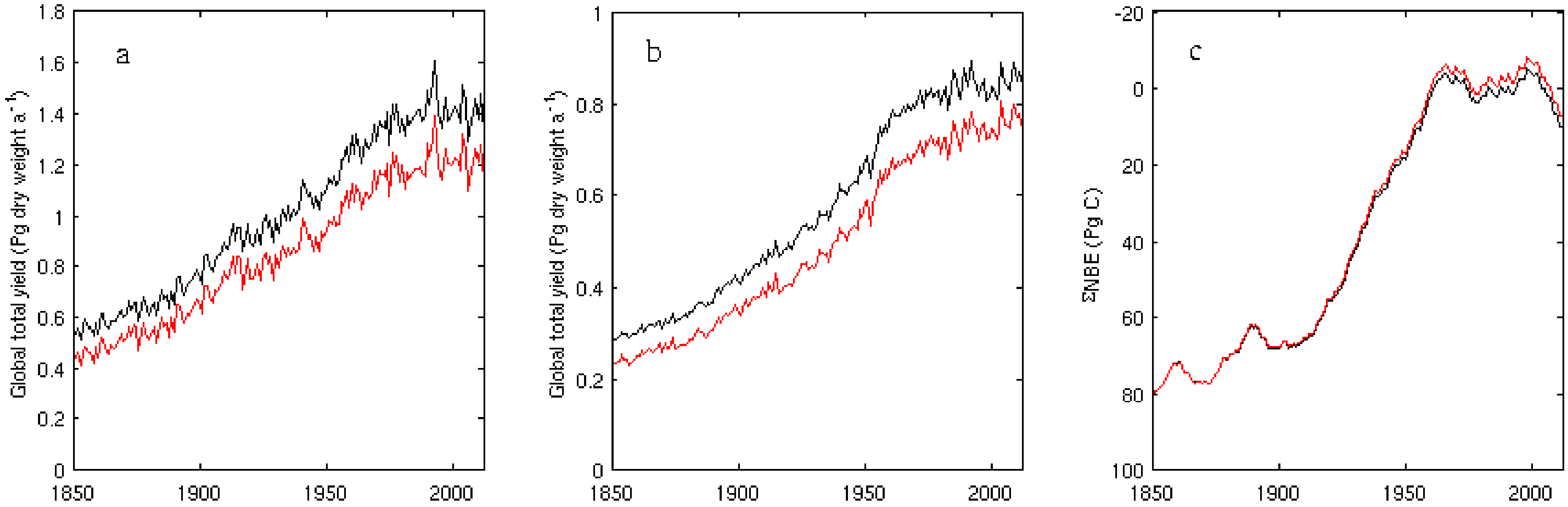
Why is the difference so large?

Using factorial simulations we can isolate the different elements of the LUC emission:

1850-2012 accumulated LUC fluxes (Pg C)

Flux	Detailed crops	Crops-as-grass
Net deforestation (pre-ind. biomass)	142	141
Net deforestation (env. change)	7	5
Lost potential sink capacity (veg.)	34	36
Indirect soil flux	**41**	**-52**
Lost potential sink capacity (soil)	-9	-10
Total	**215**	**120**

Why is the difference so large?



Influence of crop representation on the carbon cycle

Uncertainty:

Direct emissions from land-use change 1850-2005, i.e. Deforestation in LPJ-GUESS simulations (process included in IPCC AR5 GCMs)

Emissions from harvest/grazing 1850-2005 in LPJ-GUESS simulations (mostly balanced by decrease in soil respiration flux)

Harvest is a massive gross flux of carbon to the atmosphere. Ignoring harvest not only ignores a substantial net flux, but all the uncertainties associated with the gross flux (and the balancing soil respiration flux)