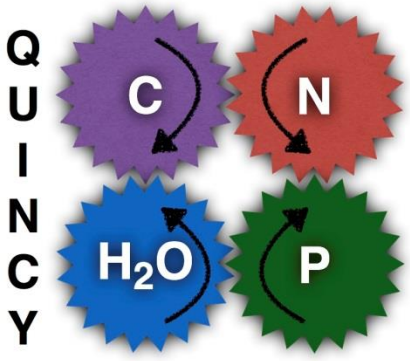

Historical carbon dioxide emissions caused by land-use changes are possibly larger than assumed

Accepted version

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Supplementary Material

Supplementary Table 1

Model components relevant for the calculation of F_{LULCC}. All models include deforestation and regrowth after abandonment; all models respond to observed changes in climate and atmospheric CO_2 concentration. For further details on individual models and simulations, see methods.

	JSBACH	**JULES**	**LPJ**	**LPJ-GUESS**	**LPJmL**	**LPX**	**OCN**	**ORCHIDEE**	**OSCAR**	**VISIT**
Wood removal through harvest	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Shifting cultivation	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes
Managed land represented by harvested grass	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes (cropland area only)
Crop functional types and other cropland management features	No	No	No	Yes	Yes	No	Yes	No	Yes	No
Wildfire	Yes	No	Yes	Yes	Yes	Yes	No	No *WH*)/ Yes (*SC*)	Yes	Yes
CN interaction	Yes	No	No	Yes	No	Yes	Yes	No	No	No

Supplementary Table 2: Cumulative fluxes from 1901 to 2014 (exceptions: LPJ, finish in 2013; LPJ-GUESS for the *MC* and *GH* cases, which finish in 2012; see methods). Data are adopted from [1-3], and from additional simulations (see methods). F_{LULCC} is the difference between a simulation in which land use, climate and atmospheric CO_2 levels vary through time compared to a reference simulation with land use fixed at pre-industrial levels. Individual models differ in the degree to which they represent the processes of interest and therefore not all processes are included in all models. For modelling groups that include *SC*, *WH* and/or *MC* in their current standard model version $F_{LULCC,0}$ was calculated by subtracting the individual contributions, assuming additivity. Likewise, for models that do not include these, $F_{LULCC,1}$ was approximated by adding the individual component fluxes.

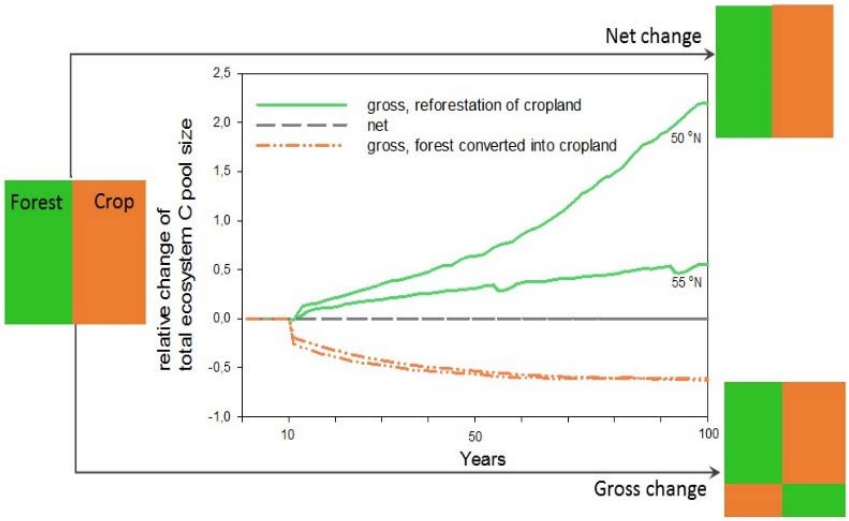
SC: shifting cultivation in tropical regions (gross *vs*. net area transitions); *WH*: wood harvest; *GH*: harvest aboveground biomass in cropped and pasture areas, with crop vegetation represented by grass functional types; *MC*: managed crop parameterisation (compared to harvested grass); for all models see methods on details about implementation.

$F_{LULCC,0}$: "Baseline" land-use change related fluxes (net transitions, no wood harvest, crops represented by the grass PFT).

$F_{LULCC,1}$: Land-use change related fluxes accounting for new processes; 1 stands for either *SC, WH, GH* or *MC*. In case of LPJ-GUESS, and OSCAR values for $F_{LULCC,0}$ in *MC* are similar to $F_{LULCC,1}$ in the *GH* case due to the factorial nature of the simulation experiment.

Units: Pg C a^{-1} except for the ratio in the last column (unitless).

Model	Process	$F_{LULCC,0}$	$F_{LULCC,1}$	Delta F_{LULCC}	$F_{LULCC,1}$: $F_{LULCC,0}$
JSBACH	*SC*	67.2	98.5	31.3	1.5
LPJ	*SC*	175.4	207.4	32.1	1.2
LPJ-GUESS	*SC*	156.1	201.3	45.3	1.3
LPX	*SC*	91.3	137.2	45.9	1.5
OSCAR	*SC*	37.0	47.7	10.7	1.3
ORCHIDEE	*SC*	92.2	121.9	29.7	1.3
VISIT	*SC*	53.2	110.5	57.3	2.1
Average		*96.1*	*132.7*	*36.0*	
JSBACH	*WH*	67.2	80.4	13.2	1.2
LPJ	*WH*	175.4	213.9	38.6	1.2
LPX	*WH*	91.3	115.1	23.8	1.3
OCN	*WH*	139.8	163.7	23.9	1.2
ORCHIDEE	*WH*	162.4	200.2	37.8	1.2
OSCAR	*WH*	37.0	47.4	10.4	1.3
VISIT	*WH*	53.2	124.7	71.5	2.3
Average		*103.8*	*135.1*	*31.3*	
JULES	*GH*	95.8	103.6	8.7	1.1
LPJ-GUESS	*GH*	100.4	153.5	53.1	1.5
OSCAR	*GH*	37.0	112.2	74.2	3.3
Average		*77.6*	*123.2*	*45.0*	
LPJ-GUESS	*MC*	153.5	183.7	30.3	1.2
LPJmL	*MC*	197.9	196.7	-1.3	1.0
OSCAR	*MC*	112.2	123.9	12.7	1.3
Average		*154.5*	*168.1*	*13.9*	



Supplementary Figure: Gross vs. net Changes. Example is for a gridcell that at time t=0 has 50% crop and 50% natural forest cover and undergoes in the next time-step t=1 (arrows) about 20% conversion of forest area to cropland, and 20% of cropland is reforested. The time series of simulated changes in carbon pools shows an example simulation from LPJ-GUESS for two temperate forest grid locations, for 100 years with constant climate (repeated every 30 years) and CO_2 concentration, and land-cover change imposed after 10 years. If only net-transition are considered, the total area changes and land-cover change related emission flux (grey line) will be zero. In the gross-transition case, deforestation will result in a rapid initial loss of carbon from above ground biomass and litter, followed by smaller losses from soil legacy fluxes (orange lines, values < 1 indicate a loss of C compared to t=0), while the deforested area will begin to accumulate carbon more slowly (green lines).

References:

1 Stocker, B. D., Feissli, F., Strassmann, K. M., Spahni, R. & Joos, F. Past and future carbon fluxes from land use change, shifting cultivation and wood harvest. *Tellus Series B-Chemical and Physical Meteorology* **66**, doi:10.3402/tellusb.v66.23188 (2014).

2 Wilkenskjeld, S., Kloster, S., Pongratz, J., Raddatz, T. & Reick, C. H. Comparing the influence of net and gross anthropogenic land-use and land-cover changes on the carbon cycle in the MPI-ESM. *Biogeosciences* **11**, 4817-4828, doi:10.5194/bg-11-4817-2014 (2014).

3 Pugh, T. A. M. *et al.* Carbon emission from land-use change is substantially enhanced by agricultural management. *Environmental Research Letters* **10**, doi:10.1088/1748-9326/10/12/124008 (2015).