Supplement of Earth Syst. Dynam., 8, 91–111, 2017
http://www.earth-syst-dynam.net/8/91/2017/
doi:10.5194/esd-8-91-2017-supplement

Supplement of

Uncertainties in the land-use flux resulting from land-use change reconstructions and gross land transitions

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Supplementary Information

Table S1. Global carbon stocks and fluxes from this study compared against literature studies where multiple land-use data sets were used. Total C stocks comprise besides vegetation, soil and litter C also C in the product pool. Averaging periods were selected according to the available studies.

Study	Land use model	E_{LUC} [Pg C a^{-1}]			Cumulative E_{LUC} [Pg C]	Loss in total C stocks due to LUC activities [Pg C]		Vegetation C stocks [Pg C]		Soil C stocks [Pg C]		LUC model and additional information
		net			net	net	gross	net		net		
Averaging period		1980-1989	1990-1999	2000-2005	1900-2005	1700-1992	1700-1992	1850-1859	1981-2000	1850-1859	1981-2000	
This study	LUH1	1.10	1.18	1.44	137	-103	-143	438	404	1 431	1 401	
This study	RAMA	1.40	1.57	1.61	154	-104	-	473	430	1 497	1 470	
This study	HYDE	1.55	2.65	2.20	171	-97	-	476	433	1 505	1 479	
This study	LUH2	1.31	1.36	1.51	139	-87	-	447	414	1 443	1 418	
This study	Average and uncertainty	1.34 ± 0.19	1.69 ± 0.66	1.69 ± 0.35	150 ± 16	-98 ± 8	-	458 ± 19	420 ± 14	1 469 ± 38	1 442 ± 39	
Arora and Boer (2010)	2 models	-	0.55 ± 0.42[b]	-	-	-	-	554 ± 13[b]	541 ± 0[b]	1 585 ± 40[b]	1 598 ± 57[b]	CanESM1 model; LUC used was (1) cropland from Ramankutty and Foley (1999), (2) cropland and pasture based on Klein Goldewijk (2001)
Houghton et al. (2012)	13 models	1.14 ± 0.23	1.12 ± 0.25	-	-	-	-	-	-	-	-	synthesis of 13 estimates of different sources see their Table 1
Jain et al. (2013)	3 models	1.88 ± 0.26[a]	1.68 ± 0.18[a]	1.40 ± 0.21[a]	167 ± 9.6[a]	-	-	-	-	-	-	ISAM C-N model; used LUC data were Houghton (2008), Ramankutty and Foley (1999), Klein Goldewijk et al. (2011)
Shevliakova et al. (2009)	2 models	-	-	-	-	-186 ± 35[b]	-267 ± 38 [a,b]	-	-	-	-	LVM3V model; LUC used was (1) cropland from Ramankutty and Foley (1999) and pasture from Klein Goldewijk (2001), (2) cropland and pasture based on Klein Goldewijk (2001); proportional scaling of natural vegetation for each combination

[a]including wood harvest, [b]no nitrogen limitation.

Table S2. European carbon stocks and fluxes from this study compared against literature studies where net and gross land-use transitions were considered. Averaging periods were selected according to the available study.

Study	**Land use model**	**Vegetation C stocks [Tg C]**						**LUC model and additional information**
		net			**gross**			
Averaging period		1981-1990	1991-2000	2001-2010	1981-1990	1991-2000	2001-2010	
This study	HILDA	9 227	9 788	10 518	9 061	9 626	10 360	
This study	LUH1	11 518	12 436	13 484	-	-	-	
This study	Average and uncertainty	10 373 ± 1 620	11 112 ± 1 872	12 001 ± 2 097	-	-	-	
Fuchs et al. (2015a) and personal communication	Fuchs et al. (2015b)	11 228	12 228	12 876	11 360	12 399	12 916	C stocks and fluxes were derived using a bookkeeping method, see Fuchs et al. (2015a), at 1 km spatial resolution. Values used here were communicated personally. Note: net dataset used by Fuchs et al. (2015a) and used in this study show minor deviations due to different land use allocation in HILDA under net and gross transitions that are not considered in this study (see methods).

Table S3. Global carbon stocks and fluxes from this study compared against literature studies where net and gross land-use transitions were considered. Total C stocks comprise besides vegetation, soil and litter C also C in the product pool. Averaging periods were selected according to the available studies. Numbers in parentheses in gross columns give the deviation from the corresponding net value.

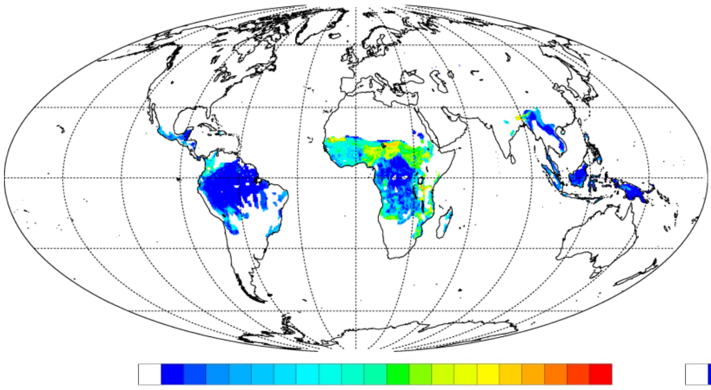
Study	**Land use model**	**E_{LUC} [Pg C a^{-1}]**								**Cumulative E_{LUC} [Pg C]**							**Loss in total C stocks due to LUC activities [Pg C]**		**LUC model and additional information**
		net				**gross**				**net**			**gross**				**net**	**gross**	
Averaging period		1850-2005	1980-1989	1990-1999	2000-2004	1850-2005	1980-1989	1990-1999	2000-2004	1850-1990	1850-2004	1850-2005	1850-1990	1850-2004	1850-2005	1860-2005	1700-1992	1700-1992	
This study	LUH1	1.14	1.10	1.18	1.46	1.31	1.28	1.41	1.68	158	176	177	181	202	204	196	-103	-143	
This study	RAMA	1.22	1.40	1.57	2.06	-	-	-	-	167	191	191	-	-	-	-	-104	-	
This study	HYDE	1.30	1.55	2.65	2.31	-	-	-	-	164	200	202	-	-	-	-	-97	-	
This study	LUH2	1.11	1.31	1.36	1.50	-	-	-	-	153	172	173	-	-	-	-	-87	-	
This study	Average and uncertainty	1.19 ± 0.08	1.34 ± 0.19	1.69 ± 0.66	1.83 ± 0.42	-	-	-	-	161 ± 6	185 ± 13	186 ± 13	-	-	-	-	-98 ± 8	-	
Olofsson and Hickler (2008)	Klein Goldewijk (2001)[d]	-	-	-	-	-	-	-	-	115[b]	-	-	148[b] (+33)	-	-	-	-	-	LPJ model run at 0.5° x 0.5° spatial resolution; areas for shifting cultivation were assigned South of 25°N based on a number of suitability criteria (e.g. not under permanent agriculture, altitude, productivity, population, etc.)
Shevliakova et al. (2009)	Klein Goldewijk (2001)[d]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-161[b]	-240[a,b] (+79)	LM3V run at 2° latitude x 2.5° longitude, spatial resolution, areas for shifting cultivation were assigned between 23°N and South of 23°S; numbers here are exclusively for LUC from Klein Goldewijk (2001)
Shevliakova et al. (2013)	Hurtt et al. (2011)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	210[a,b,c]	-	-	ESM2G, run at ~2° x 2° spatial resolution
Stocker et al. (2013)	Hurtt et al. (2011)	-	1.55	1.57	1.21	-	1.76 (+0.21)	1.83 (+0.26)	1.44 (+0.23)	-	171	-	-	196 (+25)	-	-	-	-	LPX-Bern 1.0 run at 1° x 1° spatial resolution, numbers here exclude wood harvest
Wilkenskjeld et al. (2014)	Hurtt et al. (2011)	0.90[a,b]	-	1.40[a,b]	-	1.44[a,b] (+0.54)	-	2.05[a,b] (+0.65)	-	-	-	140[a,b]	-	-	225[a,b] (+85)	-	-	-	JSBACH/CBALANCE run at 1.87° x 1.87° spatial resolution

[a]including wood harvest, [b]no nitrogen limitation, [c]calculated for pre-industrial climate and CO_2 using a bookkeeping method, [d]shifting cultivation was explicitly implemented in the land use model.

Table S4. Global carbon stocks and fluxes from LPJ-GUESS simulations started in 1700 and 1900 with the LUH1 dataset under gross and net LUC transitions.

Land use model and starting time	Averaging period	Calculation	Unit	LUH1 started in 1700		LUH1 started in 1900	
				net	gross	net	gross
E_{LUC}	2005-2014	$E_{LUC\ Net/Gross}$	Pg C a^{-1}	1.50	1.64	1.17	1.34
Cum E_{LUC}	1950-2014	$\Sigma E_{LUC\ Net/Gross}$	Pg C	89.77	104.55	74.38	91.11
Vegetation C	2005-2014	$VegC_{Net/Gross}$	PgC	421.48	386.64	420.04	385.63
Soil C	2005-2014	$SoilC_{Net/Gross}$	PgC	1 406.78	1 395.56	1 374.26	1 363.52

a



b

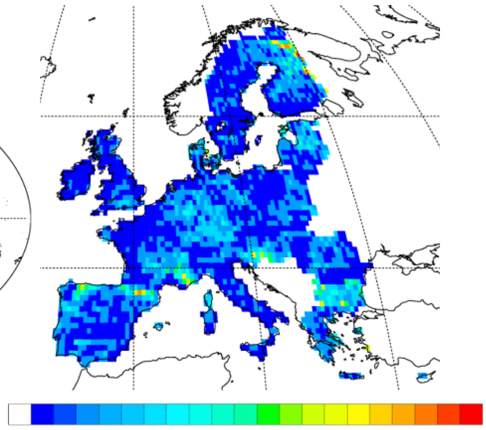


Fig. S1. Spatial pattern of areas of gross land changes globally based on the LUH1 dataset and for Europe (EU27+CH) based on HILDA (sum of converted area in addition to net changes from 1700-2014 for LUH1 and 1900-2010 for HILDA). In LUH1, gross changes are limited to tropical regions where shifting cultivation is assumed. The HILDA dataset maps gross transitions over whole of Europe.

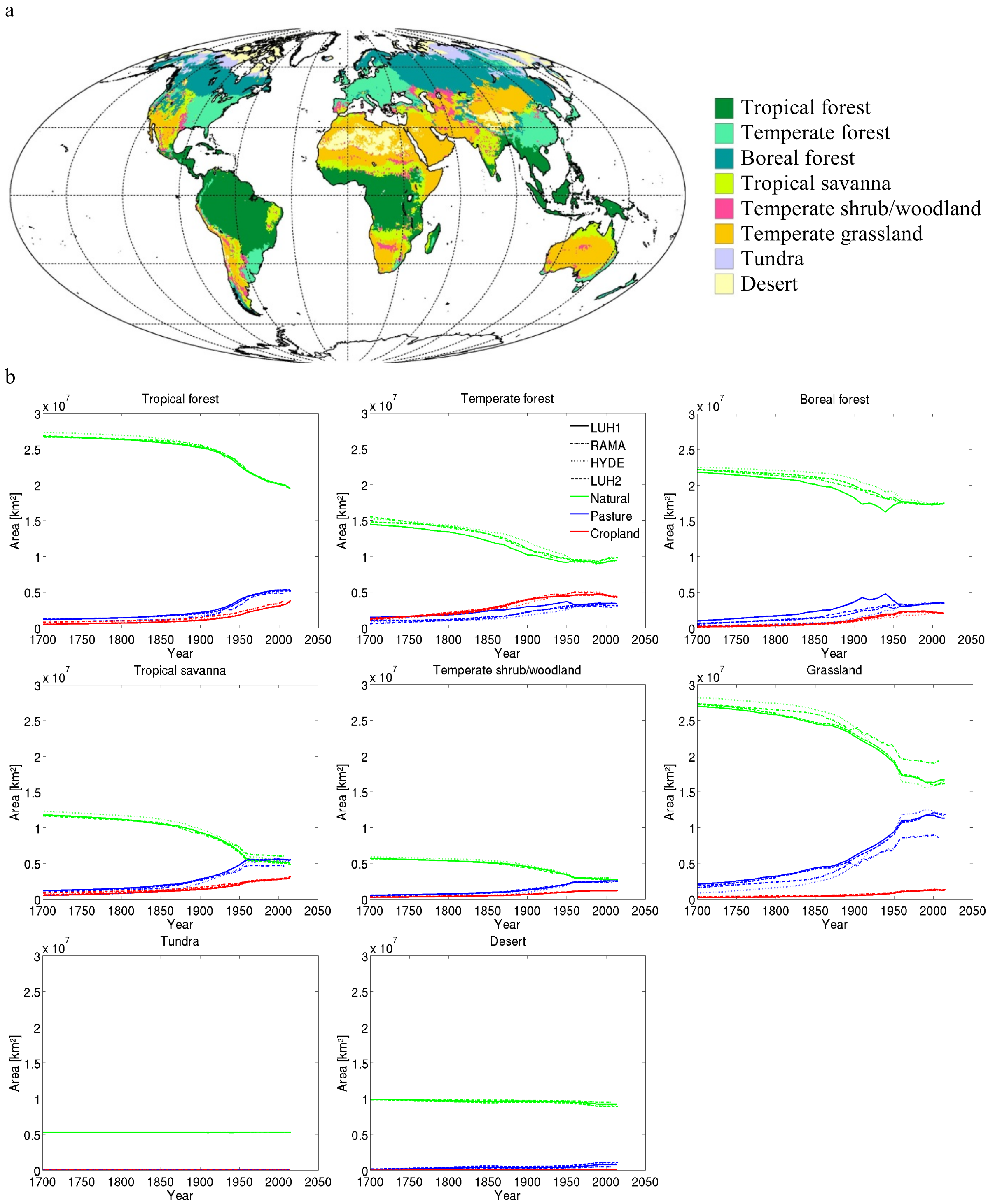


Fig. S2. Global LUC change over time for 8 biomes (a). Evolution of absolute land area of croplands, pastures and natural vegetation (including barren land) in global historical land use reconstructions (b, LUH1: solid line, RAMA: dash-dotted line, HYDE: dotted line, LUH2: dashed line) for 8 biomes. Biomes were derived with LPJ-GUESS based on average Leaf Area Index in 2005-2014 from a simulation of potential natural vegetation (see Bayer et al., 2015 for methodology and classification).

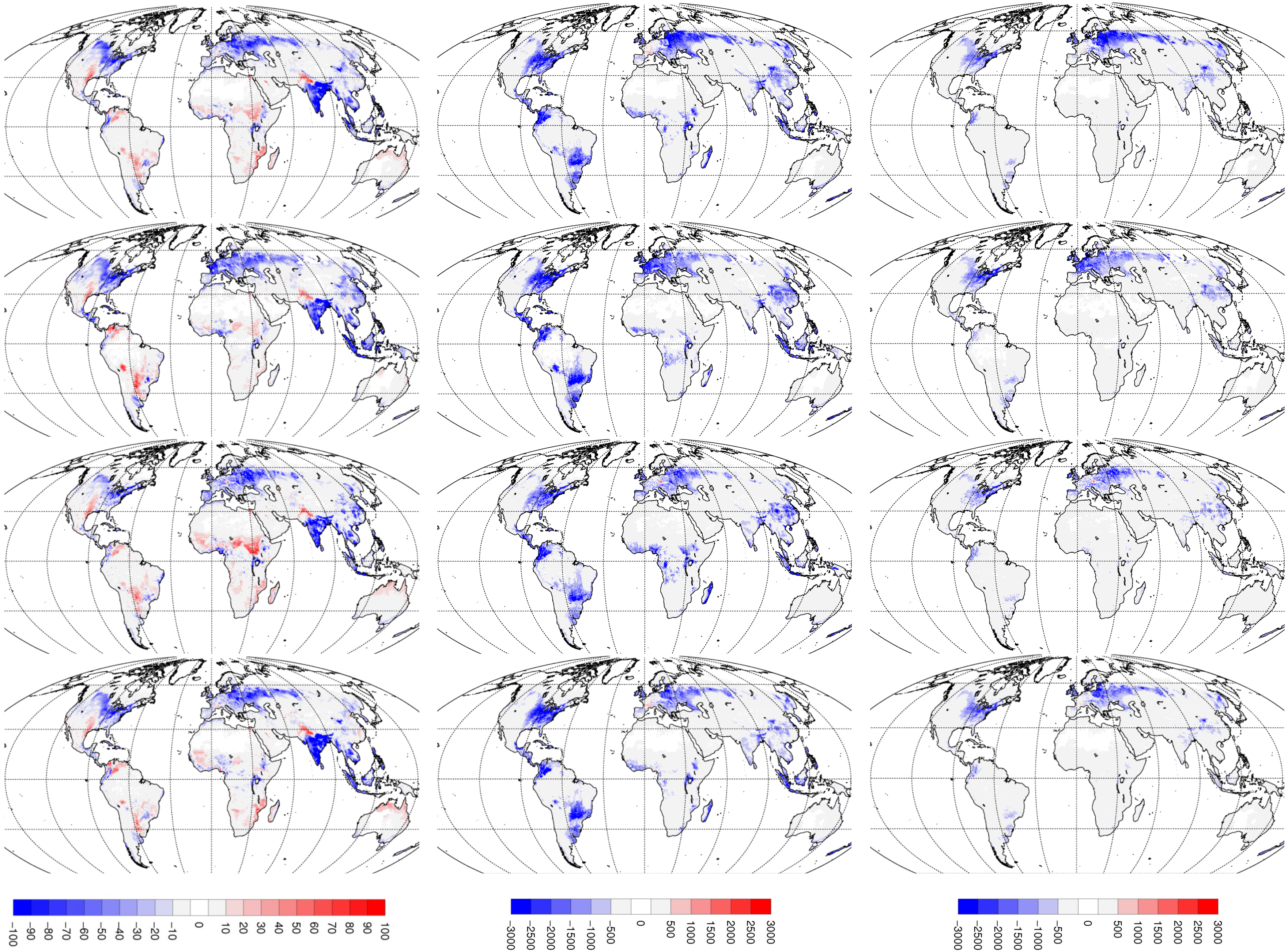


Fig. S3. Impact of land use and land cover changes on NPP (a), vegetation C (b) and soil C (c) for the four global land use reconstructions (average change due to LUC 1700-2007).

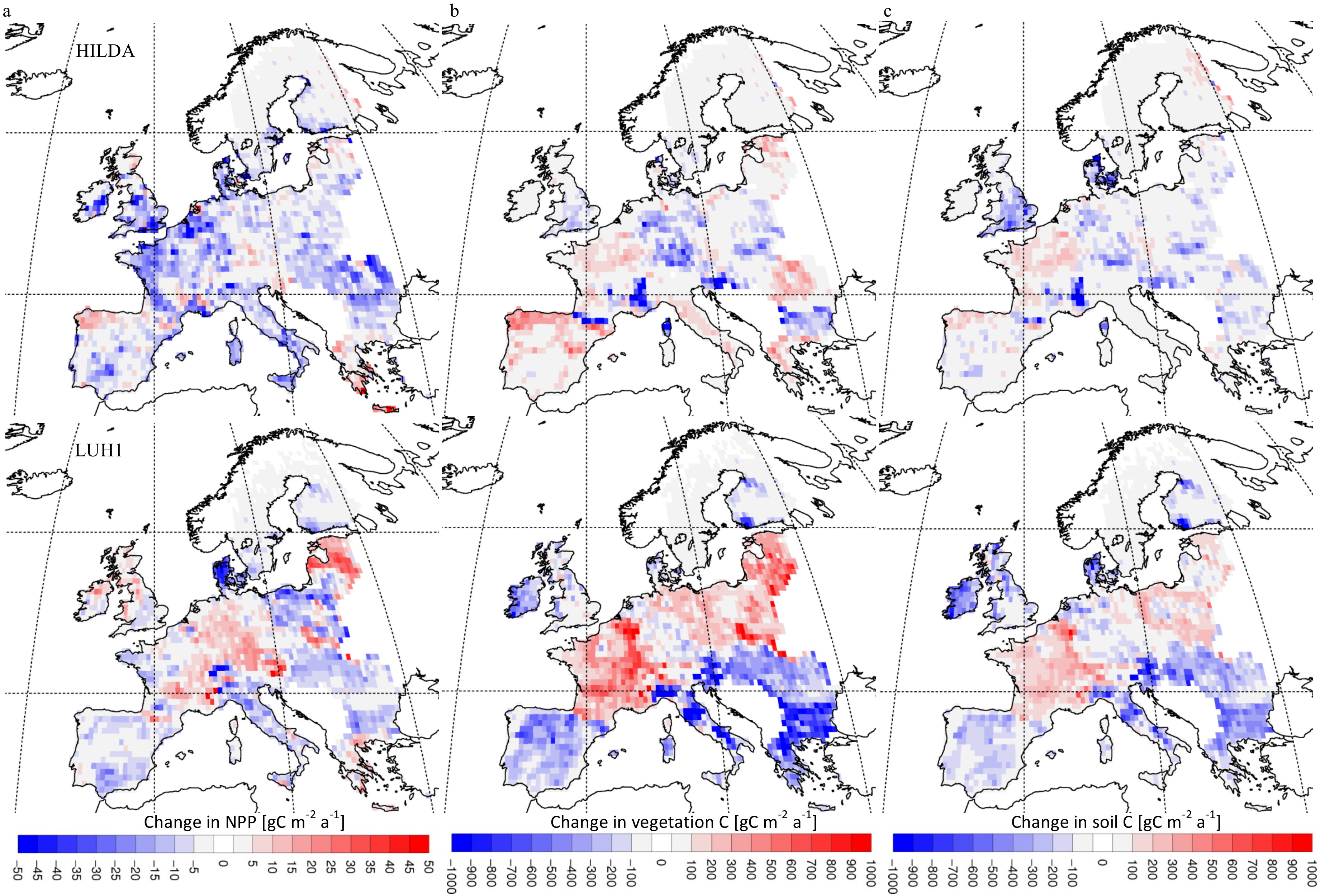


Fig. S4. Impact of land use and land cover changes on NPP (a), vegetation C (b) and soil C (c) for the two European land use reconstructions (average change due to LUC 1900-2010).

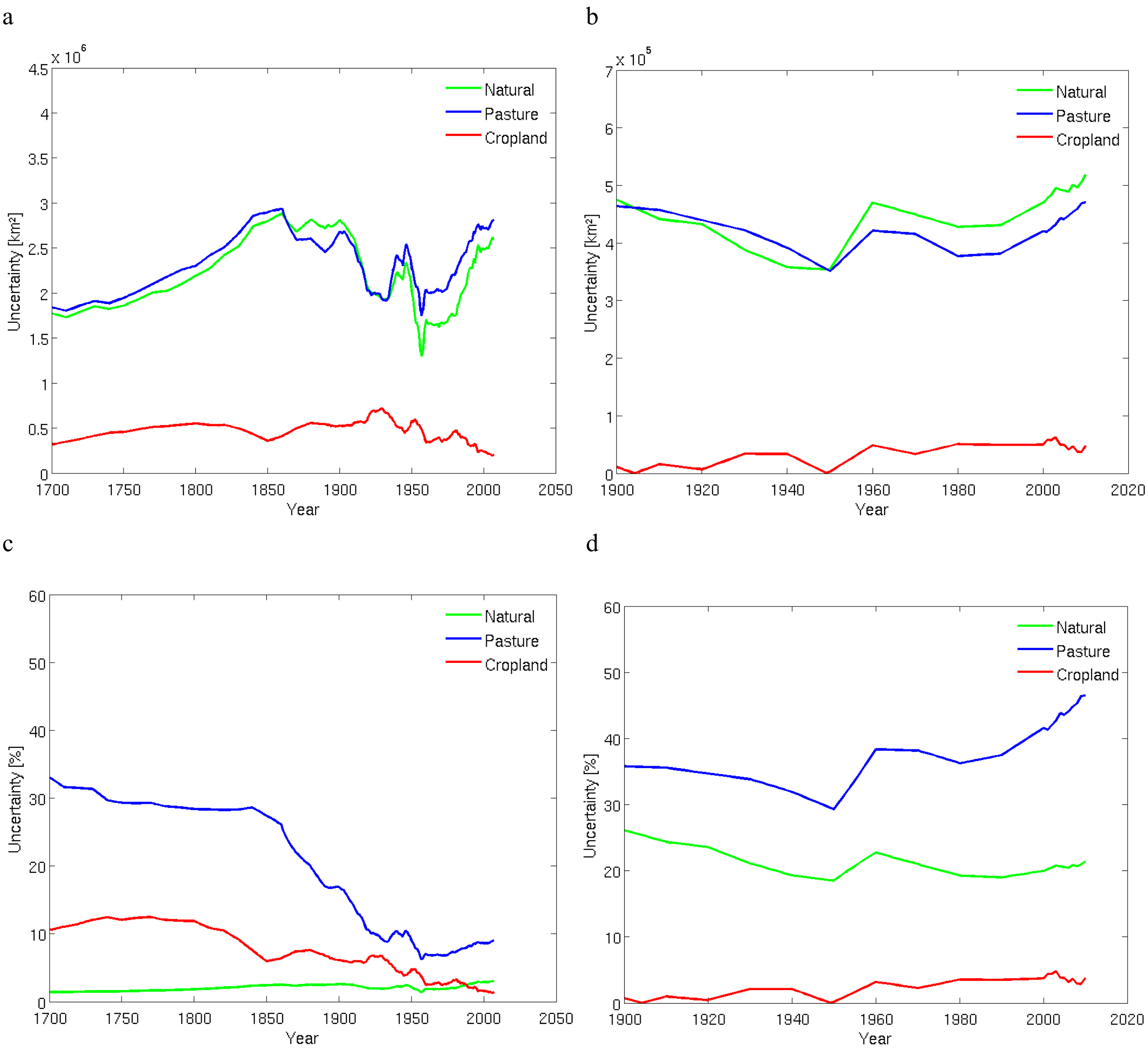


Fig. S5. Deviations in land area under natural, cropland and pasture between four global (a, c) and two European (EU27+CH) net historical LUC reconstructions (b, d). Upper panels (a, b) give the uncertainty (standard deviation) in LUC as absolute area per year and lower panels (c, d) give uncertainty as fraction of the average area of this land use in the respective year.

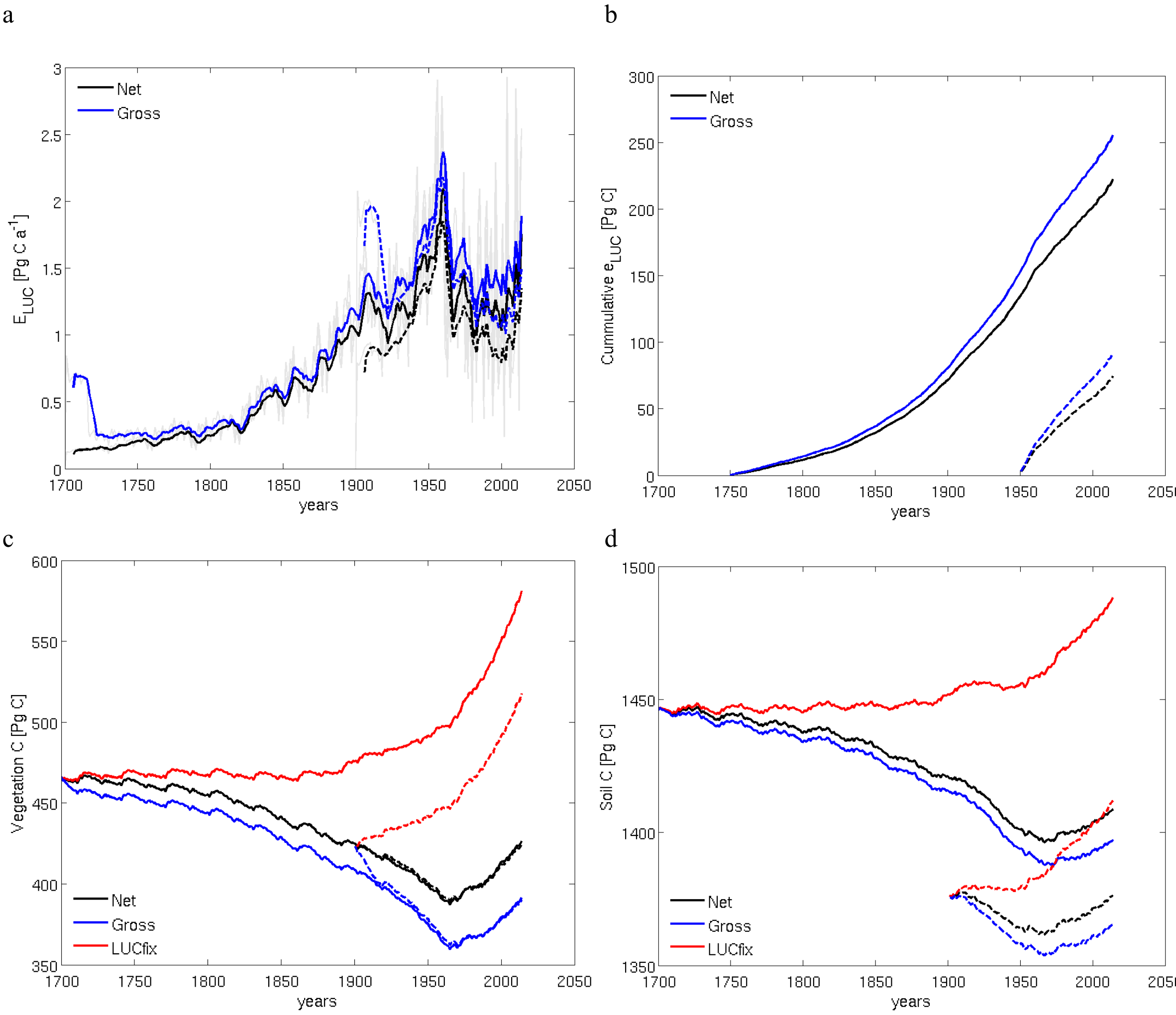


Fig. S6. Effects of different starting times on global carbon stocks and fluxes simulated with LUH1 data started in 1700 and 1900. Land use flux (a), cumulative land use flux (b), vegetation (c) and soil C (d). Flux values in (a) are given as 15-yrs averages with original values in the background. E_{LUC} was cumulated over 1750-2014 and 1950-2014 so to exclude the first years where C fluxes are adjusting to the equilibrium under shifting cultivation (see methods). C stocks differ already in the first simulation year because of different land uses in 1700 and 1900.

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